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WESTERN SPRUCE BUDWORM

FINAL REPORT

submitted to
CANADA/U.S. SPRUCE BUDWORM PROGRAM--WEST

November 7, 1980

Title: Impacts of Spruce Budworm-Caused Damage on Elk Winter Havbitat

Principal Investigator: Benjamin A. Zamora

Preforming Organization: Dept. of Forestry and Range Mgmt.
WSU; Pullman, WA 99164

CANUSA Program Activity Number: 3.1.1 -- Impacts on Wildlife and Range

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INTRODUCTION

The western spruce budworm (Choistoneura occidentalis) has defoliated millions of acres of Douglas-fir and true fir stands in the Pacific Northwest. Since the larvae of the spruce budworm are considered among the most destructive defoliators in coniferous forests of North America, the insect has become an important consideration in management of Douglas-fir and true fir forests of the Pacific Northwest (USDA Forest Service 1978). Insect defoliation of forest cover can have a substantial influence on forest resource values such as recreation, aesthetics, wildlife, wildlife habitat, and livestock range. Depending upon the resource, this influence can be positive or negative.

Forest Service management personnel in Region 1 have expressed concern about the potential detrimental impact of spruce budworm damage to elk winter range. Areas of major concern are the Beaverhead and Galletin National Forests. The main point of concern is the destruction of valuable conifer thermal cover that normally occurs as small isolated patches along the margins of the winter ranges. These stands are not normally considered to have commercial value, consequently, all management is oriented toward maintaining or manipulating the stands to enhance their value to wintering big game populations. Some concern has been expressed about the loss of understory conifers which apparently provide browse to animals. It has been suggested that control programs may be necessary to reduce or eliminate defoliating insects on such area. Information about impacts of defoliating insects on habitat of big game is simply lacking. Impact information is vital if alternatives among control strategies are to be seriously considered.

The purpose of this research project was to identify and measure impacts of spruce budworm-caused damage on elk winter habitat. Funds were granted to WSU (Benjamin A. Zamora, Principal Investigator) for the research by the Canada/U.S. Spruce Budworms Programs -- West through the USDA Forest Service Pacific Northwest Forest and Range Experiment Station. The grant was effective for the period June 7, 1979, to June 8, 1980. A time extension was granted to WSU for completion of the research with the termination date set for November 1, 1980.

The specific objectives of the project were:

1. to measure the effects of the tree defoliation and mortality on thermal cover properties of forest stands within elk winter habitat;
2. to characterize the spatial distribution, juxtaposition, vegetation, and associated site features of damaged forest stands within elk winter habitat;
3. to measure the effects of tree defoliation and mortality on understory productivity of forest stands within elk winter habitat; and
4. to formulate models which predict the potential influence of spruce budworm-caused damage of forest stands on the winter nutritional stress of elk.

STUDY AREAS

Three study areas were selected in southwestern Montana with the assistance of personnel from the Forest Service Region I Forest, Insect, and Disease Management (FIDM) Division and the Beaverhead and Gallatin National Forests. A fourth study area was selected in Yellowstone National Park, Northwestern Wyoming, with the aid of personnel from the Park staff and FIDM (Fig. 1).

Much of this region in which these study areas occur has a history of long term, extensive outbreaks of spruce budworm infestation beginning in the early 1920's (Johnson and Denton 1975). Since that time, infestations of outbreak proportions have spread and defoliation has occurred on vast acreages of Douglas fir and other susceptible forest types throughout the region.

All four study areas were selected for their importance as elk winter range and the presence of spruce budworm infestations. The areas are ecologically or environmentally similar in that they all represent Pseudotsuga menziesii communities located along the lower elevational extent of forest associations in the region. All four areas have nearly identical elevation ranges from 1850 to 2350 meters.

While forests of the study areas are dominated by the Pseudotsuga menziesii series, scattered stands representing Pinus contorta, Pinus flexilis, Picea englemanni, Abies lasiocarpa, and Populus tremuloides habitat types are also found. The forest types are interspersed with grassland and shrubland types primarily of the Festuca idahoensis and Artemisia tridentata series (Mueggler and Stewart 1980).

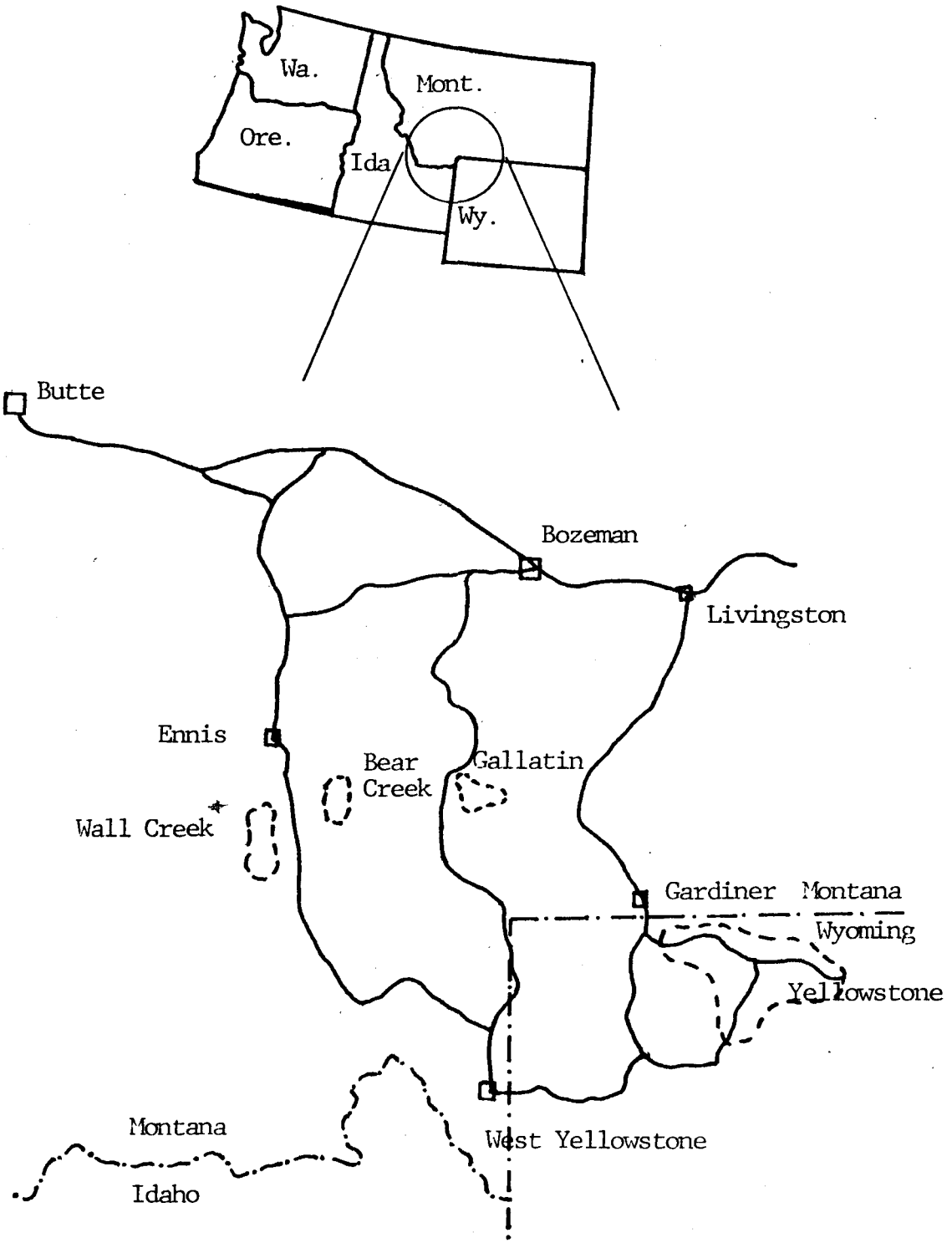

FIGURE 1 - Map of southwestern Montana showing location of study areas.

Wall Creek Study Area

The primary study area with the most extensive sampling was the Wall Creek area, located along the eastern base of the Gravelly mountain range in the Madison district of the Beaverhead National Forest. It occurs on the western side of the Madison Valley centered 24 miles south of Ennis, Montana. From Ruby Creek on the north to Wall Creek on the south, the study area encompassed approximately six and one half square miles.

Spruce budworm defoliation of Picea englemannii throughout the Ennis (then the Madison) district was first reported in 1941. The first reports of defoliation specific to the Wall Creek area were made in 1953. At that time, infestation was reportedly declining following several years of general but light defoliation throughout the area. Aerial surveys since 1950 show that visible defoliation was variable in the area with no visible defoliation occurring during 1970. Infestation levels and resultant defolation has dramatically increased throughout the latter 1970's.

Management for the Wall Creek area is oriented towards livestock grazing and big game habitat. The area includes two early summer grazing allotments for cattle which are rotated so that each allotment is grazed every other year from about June 15 to July 15. Each allotment currently supports 540 AUM's. Much of the area is used as winter range by about 1200 elk from December through March.

Major Pseudotsuga menziesii habitat types encountered on this study area include:

Pseudotsuga menziesii/Festuca idahoensis

Pseudotsuga menziesii/Symphoricarpos albus

Pseudotsuga menziesii/Calamagrostis rubescens

Pseudotsuga menziesii/Carex geyeri

Bear Creek Study Area

The Bear Creek study area is located in the Ennis district of the Beaverhead National Forest. It occurs on the east side of the Madison Valley opposite to and approximately 10 miles northeast of the Wall Creek study area. It is located east of Cameron, Montana, and stretches along the base of the Madison range from the Middle Fork of Bear Creek to about two miles south of the Trail Fork of Bear Creek. The area encompasses about three square miles.

The Bear Creek study area was selected for a comparison of sites (primarlity with west aspects) and insect defoliation from the east side of the Madison Valley, with those on the west side of the valley at Wall Creek where sites have mostly east aspects. Portions of the area are used by wintering elk which migrate from Yellowstone National Park.

The Bear Creek area includes some of the most intensive defoliation found on the east side of the valley, but in general is not as severe as the Wall Creek area.

Major *Pseudotsuga menziesii* habitat types found on the Bear Creek area include:

Pseudotsuga menziesii/Festuca idahoensis

Pseudotsuga menziesii/Symphoricarpos albus

Pseudotsuga menziesii/Calamagrostis rubescens

Pseudotsuga menziesii/Physocarpus malvaceus

Gallatin Study Area

The Gallatin study area is located mostly within the Porcupine Creek drainage on the east side of the Gallatin river canyon about 36 miles south of Bozeman, Montana. Some sampling was conducted on both sides of the Gallatin Canyon in the same area, and on the north side of Doe Creek to the west of the Gallatin River. Most of the area is part of the Bozeman District of the Gallatin National Forest. The area sampled is approximately 20 square miles.

Reports of infestation by spruce budworms specific to the Gallatin Canyon are scarce but defoliation of other locations in the Gallatin National Forest were reported in the late 1920's. Widespread defoliation over much of the Forest was reported beginning in the early 1930's (Johnson and Denton 1975). Growth forms of mature trees on much of the study area, such as branch mortality and an abundance of epicormic branching, indicates that the current outbreak has continued for several years, at least on part of the study area.

The Porcupine Creek drainage is managed for recreational use and elk winter habitat. This portion of the study area is used by an estimated 400 to 600 elk as winter range. The part of the study area west of the Gallatin River is located within grazing allotments and contains extensive clearcuts of Pinus contorta.

Major Psudotsuga menziesii habitat types encountered on the Gallatin study area include:

Pseudotsuga menziesii/Festuca idahoensis

Pseudotsuga menziesii/Symphoricarpos albus

Pseudotsuga mensiesii/Calamagrostis rubescens

Pseudotsuga menziesii/Carex geyeri

Pseudotsuga menziesii/Linnaea borealis

Yellowstone Study Area

The Yellowstone study area is located in the northern part of Yellowstone National Park. It includes low elevation stands in a zone from one half to two miles wide mostly along the highway from Mammoth to Tower Falls. This band stretches along either side of Lava Creek, the south side of the Yellowstone River, and for a short distance along the south side of the Lamar River. The area sampled covers approximately 30 sqare miles.

The area was selected not only because of its importance as elk winter range, but also because the area has been affected by continuing, severe spruce budworm defoliation for an extended period of time. The northern Yellowstone area involved one of the first documented spruce budworm outbreaks reported in western North America. Outbreak level infestations were first reported in 1923, but are believed to have existed since at least 1919. High levels of defoliation and tree mortality were reported until 1925. New outbreaks were reported beginning in 1950. Defoliation continued and increased to high levels throughout the northern part of the park. In 1955, 55,410 acres of Douglas-fir were aerially sprayed with DDT insectiside along the Yellowstone River from Mammoth to Tower Falls. Defoliation has occurred at various levels in this area since that time (Johnson and Denton 1975).

Since this study area is part of Yellowstone National Park, livestock grazing or logging have been prohibited since the early 1900's. Limited impact recreation and preservation of wildlife and pristine vegetation conditions are the primary management goals for the area. The area is used by large numbers of elk and few bison during the winter and by moose year round. The elk use the area throughout mild winters,

or into January during severe winters when they usually move on to lower elevations.

The understory of some stands appear to have been significantly affected by heavy grazing of wintering elk and in some cases by moose. In some parts of the study area, Douglas fir stands are widely dispersed across broad parklands of grassland and shrubland associations.

Major Pseudotsuga menziesii habitat types found within the study area include:

Pseudotsuga menziesii/Festuca idahoensis

Pseudotsuga menziesii/Symphoricarpos albus

Pseudotsuga menziesii/Calamagrostis rubescens

Pseudotsuga menziesii/Physocarpus malvaceus

Pseudotsuga menziesii/Linnaea borealis

METHODOLOGY

Study Design

It was hypothesized that the major effect of spruce budworm outbreaks on big game habitat would be a change in the balance between cover and foraging areas within the habitat. Where cover is limiting, severe damage to stands which provide critical thermal and hiding cover for animals could have a substantial detrimental impact on big game populations. This is especially true in winter range areas where reduction of thermal cover can increase winter thermal stress experienced by elk. Existing forage supplies may or may not be adequate to offset the added nutritional stress imposed on the animal. If large nutritional deficits are experienced by animals through the winter, increased mortality and lower specific natality rates in elk populations would be expected, especially under very severe winter conditions. Where cover is not limiting, severe damage could provide new foraging areas which could substantially benefit populations.

Impact within a specific unit of habitat will be a function of:

1. severity of damage caused to individual stands by defoliation;
2. extent and uniformity of damage throughout individual stands;
3. number and dispersion of damaged stands throughout the habitat of a population;
4. juxtaposition of damaged stands in relation to critical habitat components such as cover and foraging areas;
5. stand management activity following budworm damage;
6. habitat value of individual stands to big game populations prior to damage; and

7. opportunities available to populations within the affected habitats to adjust areas of use to compensate for the loss of critical habitat components.

Items 1-4 and 6 were the primary factors investigated during the single field season allowed by the Spruce Budworm Program for this project.

Four study areas were selected for the vegetation survey as previously described. Each area constituted an important winter range for elk herds of the region.

Stand Selection

A total of 331 macroplots were sampled across all four study areas. One hundred-three plots of the total were located specifically to measure impacts on thermal cover stands and will be referred to as intensive plots. The remaining 228 plots were sampled as part of the reconnaissance study and will be referred to as such. One macroplot was sampled in each stand or location.

Within the selected study areas, stands were subjectively selected for sampling on the basis of four hierchial criteria as follows:

1) Forested areas, where tree cover formed a continuous vegetation cover, were separated out according to their spatial discontinuity. This was accomplished both by the use of aerial photography and field observation with the exception of the Yellowstone National Park study area for which no aerial photography was available until near the end of the sampling period.

2) These continuously forested areas were further broken down into distinct, relatively uniform segments on the basis of distinguishable differences in degree of defoliation. This was done by on the ground

surveillance. At this level, no attempt was made to make separations within those segments where an apparent gradient of degree of defolation occured across the segment, but the gradient was noted to ensure that further segregation adequately sampled across the gradient.

3) Portions of these uniformly defoliated areas were then separated out according to major differences in: a) tree species, composition, size, and density; and b) topographic features including relief, aspect, and topographical position. This was accomplished by the use of aerial photography and field surveillance.

4) These segments were then broken down into individually homogeneous stands according to differences in site and/or stand structure. This segregation was made with consideration of topographic position, microrelief, understory composition and structure and productivity, and overstory structure. This level of separation is what the term "stand" will refer to throughout this report.

More than one location or stand was sampled within a segment whenever the segment was large or there appeared to be a gradual gradient in damage or stand structure across the segment that was not adequately segregated out at other levels.

In forest segments where high variability in site and community structure made it impossible to designate separate, uniform stands for sampling, then a stand was selected for sampling that appeared to be representative of the most common condition throughout the segment. The objective behind the above procedure was to define stands for sampling that are relatively ecologically homogeneous.

Nearly all sampling was restricted to those stands where Pseudotsuga menziesii was clearly the overstory dominant. Some less intensive plots

were placed in other forest types for providing descriptive and comparative information for the study areas.

Sampling was somewhat more intensive on the Wall Creek area than on other study areas. Small relatively insignificant sites or stands were generally not sampled individually on any of the study areas, but it is felt that a representation of most community types and site conditions within the study areas were sampled. Non-uniform areas were generally sampled more extensively than relatively uniform areas on a per-unit area basis, both as a function of the stand selection procedure and of time constraints.

Site Characteristics

For each macroplot, the following site variables were determined:

1. slope aspect (using a hand-held compass),
2. slope steepness (using a clinometer),
3. elevation (from topographic map or altimeter),
4. microrelief of soil surface,
    a. straight
    b. undulating
    c. convex
    d. concave
5. landform,
    a. slope
    b. drainage bottom
    c. ridge
    d. bench

6. macrorelief, and
    a. mountainous
    b. foothill
    c. pediment
    d. floodplain
7. position on slope or landform.
    a. slope, upper 1/3
    b. slope, middle 1/3
    c. slope, lower 1/3
    d. drainage bottom, side
    e. drainage bottom, bottom
    f. ridge, top
    g. ridge, side slope
    h. bench, front
    i. bench, middle
    j. bench, back

Measurement of Overstory Structure and Damage

Measurements of the overstory and understory trees selected to provide data for the following variables:

1. Overstory (trees < 1.4 m tall) characteristics
    a. density (individuals per unit area)
    b. basal area
    c. height of stand
    d. length of live crown
    e. crown closure (canopy coverage)
    f. crown volume vertical distribution

g. refoliation and foliage density in crown

h. crown damage stratified according to layers

i. age

2. Understory tress (tress < 1.4 m tall)

a. density by species and damage class

b. crown volume

Overstory parameters were sampled for each stand using two different plots with common centers. Trees less than 12 cm in DBH but more than 1.4 meters in height were sampled using a 1/300 acre plot, and all trees with greater than 12 cm DBH were sampled using a variable radius plot, the size of which was determined by use of a Speigal Relaskop with basal area factors of 10, 20, and 40. The basal area factor used was chosen so that the plot contained at least five and usually 7 or 8 trees. Trees on the border of the variable plot, for which it could not be determined if they were in or out of the plot were identified and measured as well. For these border trees, the distance from the center of the plot to the border tree was measured in order that the true status of the tree could be calculated.

All trees in both plots were measured for percent slope to (1) the top of the tree, (2) the top of the live crown in trees with dead tops, (3) the base of the live crown at both its lowest and highest point, (4) and the base of the tree at eye height. The distance from the tree to the point at which these slope measurements were made was also recorded. For dead trees killed by defoliations, measurements to the base of what appeared to have been live crown when the tree was alive was made so that these trees could be included in determining stand defoliation indices that would reflect total stand impact by the spruce budworm population.

On the intensive plots additional percent slope readings were made to points within the vertical strata of the crown that separated the crown into obvious layers of defoliation, foliage density, or structural changes resulting in abrupt changes in crown volume. From this, the length of each of these layers could be determined. The species of each tree was recorded and indications were made as to whether the tree was dead or alive. For dead trees it was indicated whether or not the death was likely attributable to spruce budworm defoliation.

Diameter at breast height was measured for each tree and its crown dominance class was recorded.

Crown classes were assigned to dead trees enough to be killed by spruce budworm defoliation with the assumption that the current status is somewhat similar to its status at the time of death. This was done so that these trees could be included in determining differential impact of spruce budworm defoliation according to corwn dominance status.

Trees less than 1.4 meters tall were counted by species within the 1/300 acre plot. These density counts were made for two reproduction size classes; class "A" included seedlings less than 5 cm tall and class "B" included seedlings and saplings more than 5 cm tall.

Degree of spruce budworm defoliation of the tree canopies was estimated individually for each tree that was greater than 1.4 meters in each plot. Average defoliation of the reproduction classes or those trees less than 1.4 meters tall was estimated collectively by one defoliation value. For the larger trees, reconnaisance plot defoliation estimates were made for each vertical third of the crown. Estimates for intensive plots were made for each vertical crown layer as determined by the criteria

stated previously. Defoliation was estimated on the reconnaisance plots in 25 percent increment classes, and the midpoints for each of those classes were used in the analyses. Defoliation on the intensive plots was recorded in 10 percent increment classes.

Increment cores were taken from at least three trees of each species within the plot. For those plots including species other than Douglas fir, but not containing three mature trees of that species, increment cores were taken from trees outside the plot but as close as possible to the plot and still located within the same "stand" as the plot.

A single overstory coverage measurement was made with a Lemman densiometer at the center of each macroplot. For selected plots, a 180^{o} hemispherical lens photograph was taken of the overstory.

Forage Production

Forage production sampling was conducted to determine forage available for elk winter use and to assess potential increases in forage production as a consequence of budworm defoliation. All sampling was conducted during the last month of the summer field season. This gave the best estimate of production available to wintering elk populations that could be obtained under the time constraints of the project's field season.

Sampling was concentrated in the forest stands and coordinated with the 100 m^2 macroplots used for overstory sampling. This provided a data base for developing an overstory structure-understory production regression model which can be used to assess changes in understory production caused by overstory defoliation and mortality. Four 4.8 sq. ft. forage production microplots will be located within each 100 sq. meter fixed plot. One microplot was clipped for each macroplot. The clipped microplot was randomly chosen prior to establishing the macroplot center. Each

succeeding microplot was then estimated for total forage weight as a percentage of the clipped. The percent composition of each species within each microplot was estimated to the nearest percent. For the clip microplot, species composition was first estimated, then clipped and separated by species and bag for drying and weighing at a later time. Clipping was restricted to 2.5 m above the forest floor. All samples were dried in a forced air oven for 16-18 hours at 55^{o} C and weighed to the nearest tenth of a gram. The data was converted to kg/hectare.

Additional sampling was carried out in forage areas surrounding the forest stands. Major community types were identified and sampling conducted to determine the contribution of the food supply available to elk.

Elk Use

Pellet group surveys were conducted in the immediate area of each macroplot. Nine 1 x 15 meter belt transects were sustematically located in conjuction with the macroplot center. The pattern of transect location consisted of three rows of three belt transects with the center transect directly over the macroplot. Old and previous winter deer and elk pellets were counted within each transect. The data was summarized into composite values of animal day's use for the stand.

Additional pellet group surveys were conducted in areas adjacent to the stands in the Wall Creek Study Area to determine general use patterns related to the forest stands.

Elk Diets and Diet Quality

Food habits were determined for elk on the Wall Creek study area by fecal analysis, following sample collection and analysis procedures outlined by McArthur (1977), McReynolds (1977), and Korfhage et al. (1978). Analysis was conducted by the Wildlife Habitat Services at Washington State University. Five collections of fecal pellets will be obtained during the winter on the Wall Creek elk winter range. Collections were made in December, January, February, March, and April. Personnel from the Ennis Ranger District collected pellets at two week intervals. Samples were combined for each month for analysis.

Forage quality was evaluated for in vitro digestible energy and digestible protein on the Wall Creek Study Area. Forage samples were collected for plant species once during each of the five months. Dried samples were ground in a Wiley mill (60-mesh) before analysis. In vitro digestion procedures follows Tilley and Terry (1963). A model 1242 Parr adiabatic calorimeter was used to determine gross and digestible energy. Crude and digestible protein analysis procedures follows AOAC (1970) procedures. Diet quality was evaluated by weighing each forage species' digestible protein or energy value, for a particular collection date, by the proportion which that species comprised in the diet for that collection date. When summed over species, results approximated diet composition for digestible protein or energy (Thompson et al. 1973, Mautz et al. 1974). Diet quality was compared with nutritional requirements, following procedures outlined by Nelson and Leege (1978). Additional analyses were conducted on six of the most widely used plant species on the area to document trends in these species of digestible energy and digestible energy over

the winter period. The Wildlife Habitat Services at Washington State University completed all analysis of forage outlined above.

Measurement of Winter Environmental Conditions

Three sites were selected for documenting wind velocity and direction and ambient temperature within and outside of thermal cover on the Wall Creek study area. Two of the sites supported damaged stands. Instruments were placed inside of each stand and immediately outside of each stand. Both stands were on north-facing slopes and extensively used by elk as thermal cover. One stand was severly damaged by spruce budworm defoliation and the second stand was damaged to a lesser degree.

A third site was selected away from forest cover where the full impact of the winter weather could be measured.

Instruments were supplied by the Forest Service Pacific Northwest (PNW) Forest and Range Experiment Station Range and Wildlife Habitat Laboratory at La Grande, Oregon. The instruments were installed under the direction of Don Synder, PNW Hydrology Lab, Wenatchee, Washington, with the assistance of Dr. Ed Dealy , Range and Wildlife Habitat Lab. Personnel from the Ennis Ranges District assisted in the maintenance of the instruments and collection of the data records.

A pyranometer was set up at the Ennis Range District Office in Ennis to record daily solar radiation.

Reconnaissance of Damaged Stands

In order to broaden the scope of the study to include assessment of variation that can be expected in the status of damage across winter ranges as well as between winter ranges, reconnaissance studies were

coordinated with the intensive macroplot sampling.

The reconnaissance information collected was as follows:

1. Overstory and understory tree characteristics (collected as previously described for intensive macroplots),
2. Site characteristics (as previously described),
3. Understory characteristics:

Understory parameter were estimated in a 100 square meter circular macroplot. Species composition was recorded for the macroplot, and percent cover and frequency estimates were made for each species using classes for both parameters as follows:

Class	Percentage range	Midpoint value
1	1-5%	2.5
2	6-25%	15.0
3	26-50%	37.5
4	51-75%	67.5
5	76-95%	85.0
6	96-100%	97.5

Species were identified and named according to Hitchcock and Cronquist (1973).

RESULTS

The results of the study presented in this report are based on tabular and diagrammatic information presented in Tables 1-45 and Figures 2-12. All tables and figures have been placed in Appendix A and B of this report. Most of the results presented herein will be restricted to the intensive plot studies undertaken on the Wall Creek, Gallatin, and Yellowstone study areas.

Thermal Cover on the Wall Creek, Gallatin, Yellowstone Study Areas

Elk use of forest cover was distinctly concentrated in those stands along the lower margin of the continuous forest cover in all four study areas.

In the Wall Creek winter range, the most heavily use stands which served as thermal cover occurred on the lower one-third of the north-facing slopes of ridges which extended out from the main mountain slope into the adjacent valley. This cover frequently extended as much as one-third of a mile into the valley away from the upper mountain slope where continuous forest cover occurred. The majority of the stands are northeast facing slopes with a slope steepness averaging 28% $\pm$ 8% and elevations ranging from 1915m to 2144m.

Stand characteristics for the most heavily used thermal cover stands in the Wall Creek area are given in Appendix A, Table 2. Overstory canopy coverage averaged 60% among all the stands. Stand density averaged 956 trees/hectare; stand height averaged 14m; height to base of live crown averaged 6m; crown lengths averaged 8m; crown ratios averaged 55%; and the damage index among stands averaged 46%.

On the Gallatin study area, the terrain did not form the same kind of ridge pattern as found in the Wall Creek area but consisted of a broad mountain slope dissected by smaller ridges. The most heavily used thermal cover stands again occurred at or very close to the lower elevational margin of the continuous forest cover on the slope. The majority of the stands faced south to southwest and had an average slope steepness of 28% ± 5%. Elevations ranged from 1900m to 2197m.

Stand characteristics for the most heavily used thermal cover stands are given in Appendix A, Table 3. Canopy coverage averaged 58%, stand density averaged 915 trees/hectare; stand height averaged 11.5m; height to base of live crown averaged 4m; crown length averaged 8m; crown ratio averaged 67%; and the damage index averaged 52%.

The most heavily used thermal cover stands in the Yellowstone area occurred on southeast to northeast aspects with slope steepness averaging 15% ± 4%. These stands occurred in an elevational range of 2030m to 2161m. The terrain in the Yellowstone winter range area tends towards rolling, hilly terrain interspersed with elevated mountainous topography. A wide range of aspects are present throughout the terrain with forest cover frequently occurring as isolated stands of varying sizes. A more continuous forest cover exists in conjunction with the mountainous topography.

Stand characteristics for the thermal cover stands in the Yellowstone area are given in Appendix A, Table 4. Canopy coverage averaged 60%; stand density averaged 1769 trees/hectare; stand height averaged 12m; height to base of live crown averaged 5m; crown length averaged 6.5m; crown ratio averaged 53%; and the stand damage index averaged 70%.

Overstory damage in relation to elk use of thermal cover stands is shown in Appendix A, Table 5. Elk use based on winter pellet group counts was divided into three catagories (heavy, moderate, and light). The heavy use catagory represented the most critical thermal cover stands in the study areas. The average percent damage of these stands was in all three cases, the lowest among the use catagories. However, as indicated by the standard deviation, no significant difference was found among the catagories.

Forage Production in Damaged Stands

Forage production for all stands sampled in the Wall Creek, Gallatin, and Yellowstone study areas are shown in Appendix A, Table 6, 7, 8, and 9.

Within each study area, total production and the vegetative components of total production varied considerably among the stands sampled. This was primarily a function of differing habitat types, successional stages of the vegetation, and overstory structure. Understory tree and annual herbaceous production was extremely low among all stands of the study areas. Perennial graminoid and perennial forb production were the most consistent production components in terms of presence and range of values. Shrubs were more sporadic (reflecting the habitat type) and displayed the widest range in values. The average production values for each life form in each study area is given in Appendix A, Table 6. The actual values for each stand are given in Tables 7, 8, and 9 of Appendix A.

No consistent relationship was found between overstory coverage or percent damage index and total understory production in any of the study areas. The best correlation was between overstory coverage and total understory production among the Gallatin stands ($r^2 = 0.3140$). Reduction

of foliage in the crown of stands through defoliation was apparently not significant enough to cause statistically significant increases in understory production.

Linear regression analysis demonstrated a trend toward lower understory production with increasing canopy coverage, but in no case where the changes indicated by the regression equation found to be statistically valid.

A trend suggesting increasing production with higher percent damage indices is also apparent in the linear regression analysis of understory production and the percent damage index of the stands. But as with overstory coverage, the trends could not be statistically validated.

Elk Diets and Diet Quality

Elk diets were determined for the 1979-80 winter period over which this study was conducted. General diet composition and quality data are shown in Appendix A, Tables 10 and 11.

Trees were not found in any of the diets of elk throughout the five month sampling period. Graminoids were the most important food item constituting from 74% to 83% of the total diet. Bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), brome (*Bromus*), and bluegrass (*Poa*) were the most abundant species in the diet.

Shrubs were the next most important food item in the diet constituting 14% to 15% of the diet throughout the study period. The two most important shrubs were big sagebrush (*Artemisia tridentata*) and rabbit brush (*Chrysothamus*).

Forbs ranked third in importance in the diets, varying in composition from 3% to 11% of the diet. The two most abundant forbs in the diets were lupine (Lupinus) and buckwheat (Eriogonum).

The quality from reconstructed diets demonstrated a 1% loss of protein in the diets over the five month period (Appendix A, Table 11). Energy levels remained relatively constant with only a 186 cal/gm loss over the five month period.

Environmental Conditions in Affected Thermal Cover Stands

The temperature and wind velocity data from the six weather stations has not at this time been totally summarized for the entire period over which the instruments were operated. However, enough information was derived from the data base to prepare some comparative illustrations for four stations (Figures 2 through 9) and to use in a nutritional stress model for elk.

A sample of five continuous days in each month of December, January, February, and March was taken from data for the two most heavily used thermal cover stands on the Wall Creek range, an open north slope immediately outside one of the thermal cover stands, and the open valley floor. The five days were averaged on an hourly basis to derive a diurnal curve of temperature and wind velocity.

The following are the designations that were given each station and a brief description of the site:

Station	Description of Site
B	Open valley floor; slope = 3%, Festuca idahoensis/Agropyron spicatum habitat type.
N	North-facing slope, 10% slope, no continuous tree cover, scattered Douglas-fir individuals throughout area, Artemisia tridentata/Festuca idahoensis habitat type.

Station	Description of Site
M	Heavily used thermal cover stand, percent damage index = 69%, elevation = 2001m, slope 28%, Aspect = NNW, overstory canopy coverage = 43%, stand density = 2206 trees/ha., stand height = 8.5m, height to base of live crown = 4.4m.
P	Heavily used thermal cover stand, percent damage index = 59%, elevation = 1876m, slope = 34%, aspect = NE, overstory canopy coverage = 56%, stand density = 966 trees/ha, stand height = 10.7m, height to base of live crown = 5.2m.

The temperatures recorded at site N are not usable because of instrument failure but the wind velocity data was deemed accurate with the exception of the month of February.

As can be seen from Figures 2, 4, 6, and 8, daily temperature fluctuations for stations B, M, and P for the months of December, January, February, and March were not large within the average 24 hour period. During December, temperatures at all three stations were very similar with average lows around -5^{o} F and maximums of 2 - 3^{o} F. The January temperature pattern was elevated slightly, but the ensuing months again dropped back to patterns similar to December.

Wind velocities within the thermal cover stands were extremely low, averaging less than one mph (Fig. 3, 5, 7, 9). At station N (the north slope station immediately outside of the thermal cover stand containing station M) showed an elevated average wind velocity fluctuating around 5 mph. For the open valley floor (Station B), wind velocities were typically greater, fluctuating between 8 and 15 mph.

Models of Elk Nutritional Stress

As previously mentioned, the two primary nutrients which best reflect potential animal condition in its habitat are digestible protein and digestible energy. Comparison of the actual intake of these nutrients over time with the physiological requirements of an animal of a given weight under a given environmental regime can be used to assess nutritional stress and to identify the general survivability of the animal. This assessment is normally based on an evaluation of the entire forage cycle in the habitat of the animal. Using the results presented in the two previous sections on winter dietary quality and environmental conditions for elk on the Wall Creek range, it was possible to make an assessment of the seasonal status of the animals.

Protein:

Figure 10 illustrates the comparison between the dietary intake of digestible protein and the required level for a 236 kg elk cow consuming 4.9 kg of forage per day. As can be seen from the curves, protein deficiencies occur throughout the winter, increasing in severity as the winter progresses. This deficiency is not unexpected since the diet is composed predominantly of grasses which are low in protein content during the winter period. The four major grasses in the diet ranged from 2.3% digestible protein at the beginning of the winter period to 1.4% digestible protein at the end of the winter period.

The increasing requirement for digestible protein is the result of fetal growth in the cow. To overcome this deficiency, the cow must either draw upon body reserves to offset her needs or rely on urea recycling within the body. There two processes would likely be most effective in offsetting

the deficiency during the months of December and January. Body reserves in the liver amount to only 5% of the total body protein. However, around the first of February the deficiency increases to nearly 45 gm/day. This deficiency continues to increase to nearly 80 gm/day by the end of March. Such a deficiency could be offset only through catabolizing of muscle tissue, especially that muscle closely associated with fat deposits.

Based on the level of digestible protein intake during the month of December (Fig. 10), it is likely that cow elk enter the winter period with good body condition, meaning large body fat deposits and a buildup of muscle tissue associated with these fat deposits. The cow is entering the second trimester of pregnancy and although fetal development is taking place, fetal growth has not yet reached a critical rate. The deficiency in protein during the early part of the winter period is not severely taxing the body of the cow.

During the latter part of the winter period, protein deficiency increases nearly by a factor of two. Fetal growth now becomes more important but is still not substantial. Nearly 75% of the total fetus growth is completed in the last trimester or 25% of pregnancy. This means that protein intake during the later part of March and into June is the most critical. Protein intake deficiencies can exist prior to this time without impairment of fetus development or growth, especially if the cow is in good body condition.

What becomes most critical in this situation is the development of spring forage. Many studies have shown that spring forage will provide as much as five times more protein than winter forage. This is most important because the flush of available protein is at a time when the

fetus in the cow is growing at a rapid rate. Deficiencies in protein at this time will reduce the size of the calf at parturition, thus reducing the survivability of the calf during the first two to three weeks after birth. Any delay in the availability and development of spring forage could seriously jeopardize the specific natality rate of the herd.

Energy:

Figures 11 and 12 illustrate the trends in body weight of a 236 kg cow and 100 kg calf based on animal measured energy intake and thermal cover temperature regimes on the Wall Creek winter range.

In Figure 11, curve "A" is based on the temperature and wind conditions measured in thermal cover. Weight loss is minimal under these conditions. Wind velocities average less than one mph and essentially change very little the effective temperature influencing the animal. Based on Moen (1973) this would allow a skin temperature of approximately 28^{o} C (82^{o} F) to develop beneath 2 inch layer of hair.

By systematically reducing the ambient air temperatures by 6, 10, and 16^{o} F below the thermal cover temperatures and recalculating body weight trends based on actual digestible energy intake, an approximate temperature which would most likely cause loss of the fetus was determined (Fig. 11 and 12). Low temperatures ranging down to -20^{o} F and occurring for the duration of the winter period, would not likely cause enough body weight reduction in the cow to cause the loss of the fetus. Most studies state that a 17% body weight loss in a cow will cause abortion or reabsorption of the fetus. Constant temperatures such as used in the modelling are not likely to occur over such an extended period.

Exposure to 15 mile per hour winds such as that measured on the open valley floor of the Wall Creek range will reduce skin temperatures as much

as 26° C (79° F) where ambient temperatures average -4° F (Moen 1973). A reduction of 12° C (54° F) can occur at the skin surface under the same ambient temperature where wind speeds average 6 miles per hour. This latter condition is typical of the station located on the north-facing slope just outside of thermal cover (Station N). Based on this information, it is obvious why elk seek microsites which would minimize exposure to wind. It is important to realize that even though wind velocities were measured which would potentially affect animal condition in the area, animal behavior will often negate this potential effect. The seeking of topography and/or vegetation in its habitat with respect to barriers to wind will often reduce the affect of wind on body thermal conditions. In addition, constant wind flows creating such constant and extended depressions in the effective ambient temperature are not likely to occur.

Vegetation, Site, and Distribution Characteristics of Damaged Stands Throughout Elk Winter Habitat

The primary objective of this portion of the study was to identify those site, tree, and understory features that are related to the distribution and intensity of spruce budworm defoliation within and contiguous to the elk winter range study areas. Emphasis was placed on the relationship of differential defoliation impacts to understory community characteristics, overstory structure, and site features. The study was conducted by a graduate research assistant (Del Westover Despain). A portion of the study was written as a thesis which is attached to this report. The general results of the study are summarized below with tabular data presented in Appendix A, Tables 12 through 45.

Wall Creek Study Area

Tables 12 through 21 of Appendix A contain the tabular data for the Wall Creek area. A total of 161 plots were examined throughout the area (Appendix A, Table 12). The Wall Creek area averages 50 percent defoliation with a wide range of conditions from no defoliation to 97 percent or almost complete defoliation (Table 12). Pseudotsuga menziesii stands on the Wall Creek area were classified into seven main community types with one additional group that includes some unique high elevation stands (Tables 14-21).

The Pseudotsuga menziesii/Festuca idahoensis/Festuca idahoensis community is a fairly distinctive type on the Wall Creek area (Table 14). Without exception, these stands are located on a lower foothill area that extends the forest edge further into the Madison Valley than anywhere else on the study area. The type is usually associated with shallow soils and

and large surface rocks. The average level of defoliation for the PSME/FEID/FEID community type is 60 percent, ranging from 23 to 97 percent. This type includes both heavily defoliated stands and relatively lightly defoliated stands.

The Pseudotsuga menziesii/Festuca idahoensis/Carex geyeri community type is one of the two most common types found on the Wall Creek area (Table 15). The PSME/FEID/CAGE community type occurs on all of the aspects common to the Wall Creek area except southeast facing slopes. Most are on north to east facing slopes with a few additional stands facing north-northeast. This type occurs on a variety of topographic situations, but is most often positioned at mid slope. Average defoliation across the PSME/FEID/CAGE type is 48 percent and ranges from 12 to 86 percent.

The Pseudotsuga menziesii/Symphoricarpos albus/Carex geyeri community type is distinguished from the PSME/FEID/CAGE type primarily by the lack of Festuca idahoensis. Otherwise, the two types are similar, although some of the drier site forbs are less frequent or lacking in the former such as Eriogonum umbellatum. Defoliation in the PSME/SYAL/CAGE type averages 52 percent with a range from 12 to 92 percent (Table 16).

All of the stands in this group are located on northeasterly slopes except stand number 195 which is a high elevation southeast facing site. When compared with the PSME/FEID/CAGE community type, there is no significant difference between the two in terms of elevation of slope. By Duncan's multiple range test criterion, total basal area is the only variable which is different between the two types, being slightly lower in the PSME/FEOD/CAGE type. The Pseudotsuga menziesii/Calamagrostis rubescens/Festuca idahoensis community shows much stronger internal relationships to defoliation than previously discussed types on the Wall Creek area. This may be because of

the apparent environmental status of this group wherein it seems to bridge a gap between the Calamagrostis rubescens associations and the drier, generally less favorable conditions of the Festuca idahoensis associations (Table 17). Site topographic situations within the PSME/SYAL/FEID type are varied, but either lower slopes or ridges are by far dominant. Drainages are not represented. Of the stands sampled, the type occurs only twice on southeast slopes and both of those are at fairly high elevations. Defoliation averages 55 percent in the PSME/SYAL/FEID communities. The range is from 15 to 92 percent.

The Pseudotsuga menziesii/Symphoricarpos albus/Calamagrostis rubescens community type differs from the PSME/SYAL/FEID type primarily by the lack of Festuca idahoensis. Other bunch grasses tend to occur slightly more frequently. This type is part of the Pseudotsuga menziesii/Symphoricarpos albus/Calamagrostis rubescens habitat type. Defoliation levels for the PSME/SYAL/CARU type have an average of 57 percent and a range from 18 to 93 percent (Table 18).

The Pseudotsuga menziesii/Calamagrostis rubescens/Calamagrostis rubescens community type includes a small group of stands, but in terms of defoliation it is distinctive. Defoliation estimates average 63 percent which is the highest average for any of the community types on the Wall Creek study area. The range of defoliation is fairly narrow from 40 to 83 percent. The PSME/CARU/CARU community type is distinguished from the previously discussed Calamagrostis rubescens associations by the total lack of bunch grasses. The aspects included in this group range essentially from due north to east. The majority of the stands are on relatively steep slopes as well, and considering the size of the group, cover a wide range of topographic settings (Table 19).

The main vegetative characteristic of the Pseudotsuga menziesii/Calamagrostis rubescens/Pachystima myrsinites community type is a general dominance of Calmagrostis rubescens associated with an abundance of Arnica cordifolia and a nearly constant occurence of Pachystima myrsinites and Symphoricarpos albus. This comunity type is part of the Pseudotsuga menziesii/Calamagrostis rubescens/Calamagrostis rubescens habitat type. The stands in the PSME/CARU/PAMY type are largely associated with mid to upper slopes and average higher in elevation than any of the community types discussed thus far for the Wall Creek area. This type includes Pseudotsuga menziesii stands occuring adjacent to Pinus contorta and Picea Englemannii types on the Wall Creek area which, in conjunction with the higher elevations, indicates a probable cooler environment. The average level of defoliation in this type is 41 percent; the lowest of any of the community types on the Wall Creek with the exception of the high elevation stands discussed in the next section. Defoliation ranges from 12 to 94 percent, but values greater than 60 percent are rare (Table 20.

Vegetatively, there are three distinct kinds of communities represented by a small group of 6 high elevation stands. All were sampled on the north end of the Wall Creek study area in a portion where Pseudotsuga menziesii habitat types occur at higher elevations than elsewhere on the study area. Over much of the Wall Creek area, Pinus contorta habitat types are dominant at greater than about 2200 meters. Overall, these 6 stands average 10 percent defoliation, but four of them show no defoliation and are the only Pseudotsuga menziesii stands in the Wall Creek study area that were found to be free of any visible spruce budworm defoliation. For the purposes of between community type comparisons, these six stands were considered collectively as one group representing a unique high elevation situation (Table 21).

Within each community type, there is a variety of site, vegetation, and defoliation conditions. However, there are several trends which are recurrent throughout the data (Table 21)

In general, defoliation tends to decrease as elevation increases with uninfested stands occurring only at the highest elevations. At mid elevations this effect is sometimes overruled by effects of aspect as stands to the east or southeast are generally defoliated more than northerly slopes.

Unlike in some other study areas, percent slope is not usually an important criteria with respect to defoliation as effects of elevation, aspect, and/or overstory variables are apparently overriding. In general, slope increases with elevation.

Similarly, topographic position is diverse within each group and is difficult to associate with trends in defoliation levels. There appears a slight tendency for ridge areas to be less defoliated than other topographic situations which is in direct contrast to what is found on some of the other study areas. One possible explanation for this might be that the high winds common to the Madison Valley effect the dispersal patterns of the spruce budworm.

In comparing community types, the high elevation stands are significantly lower in defoliation than any of the other types. The PSME/CARU/CARU type is significantly less defoliated than all of the other types except the PSME/FEID/CAGE and PSME/SYAL/CAGE types. Otherwise there is little variation in defoliation between the community types. Differences between elevations, however, are highly significant with the high elevation stands at one extreme and the PSME/FEID/FEID stands at the low extreme. Other elevational differences are more subtle. The PSME/FEID/FEID stands also break out

separately because of the uncommon southerly aspects that occur within the type.

There are clearer trends in the data for overstory structure that show relationships with defoliation. Canopy cover is highest in the non-defoliated high elevation stands, and trees are by far the shortest in the PSME/FEID/FEID community type along with the height to base of the canopy. The two least defoliated communities, the PSME/CARU/CARU and the high elevation types, have significantly higher sums of diameter than any other community on the Wall Creek area. This in combination with the smaller trees involved in this sum is somewhat in contrast to the normal situation where small diameter, dense stands tend to have higher levels of defoliation. Based on the importance of elevation in these stands, it is probably an overriding effect of this variable that results in these exceptions. Otherwise, almost without exception, defoliation increases as basal area functions and diameter averages decrease. Often, height and crown functions are lower as well. Compared to the Gallatin area for example, tree density is not usually strongly related to defoliation. However, the mean values usually indicate a trend for density to be higher when defoliation is higher.

The interrelationships among site and tree variables are not always clear, but there is a tendency for total basal area and tree size average functions to increase with elevation and with shifts in aspect to the north which is consistent with the relationship to defoliation among these variables individually.

Although correlation coefficients are relatively low, correlation analysis across all the stands on the study area confirms the above conclusions for spruce budworm defoliation. By taking into account the variation that

occurs between study areas, elevation appears as the most important criteria. Most of the stand structure variables have only slightly lower correlation values. For the most part, the same overstory variables most closely related to defoliation in the within community type analyses are those which show the highest correlation in the analysis of all the data from the Wall Creek area. The main exception is height which has the highest coefficient of all the overstory variables. Apparently height shows stronger differences when the data are combined because, in reviewing the means for each type, it will be seen that the PSME/FEID/FEID community type is the only one that differs significantly in height from other community types. There is little difference in average height for the remaining types.

Gallatin Study Area

Seven major Pseudotsuga menziesii community types were identified on the Gallatin study area. These community types show distinct differences in site characteristics and serve as indicators of the various site conditions more clearly than those of the other study areas. This is due primarily to a broader topographic diversity found on the Gallatin area. The study area is described in detail in Despain's thesis which is attached so will not be covered in this report except for a brief overview of relationships. Tabular data has been included in Appendix A, Tables 22 through 30.

On the Gallatin study area, the level of defoliation occuring within a stand is dependent upon various combinations of site factors and stand structure factors. With exceptions, defoliation tends to increase in response to one or more of the following criteria (Table 22):

decreasing elevation

southerly exposures

increasing slope steepness

ridges and upper slopes

decreasing crown coverage

high tree density with low basal area and smaller diameters (usually shorter trees).

Correlation analysis across the Gallatin study area yeilds the highest relationships to canopy cover and height. Elevation is the most closely related site variable although the coefficient is low (Table 23).

Understory vegetation on the Gallatin area is often a useful indicator of the site and stand characteristics that influence the spruce budworm.

For the most part, the PSME/LIBO, PSME/SYAL/CAGE, and PSME/FEID/FEID communities are all defoliated significantly less than all the other types. The PSME/SYAL/CAGE type is defoliated the least, while the PSME/SYAL/CARU type is defoliated the most. Differences in average canopy cover show that cover is generally lowest for the more highly defoliated community types, and total basal area is higher in the least defoliated stands. Total basal area shows more relationships to defoliation in the Gallatin study area than in any of the other study areas. There is also a tendency for trees to be taller in those communities that are at lower defoliation levels. Crown lengths, and crown ratios show a similar trend, and height to base of live crown shows an opposite trend. Diameter of average basal area tends to be highest in the less defoliated communities.

Analysis of variance comparisons for the two levels of defoliation across the entire Gallatin study area reveals that elevation, canopy cover, total basal area, average basal area, average diameter, total height, height to base of live canopy, crown lengths, and diameter of average basal area, all average significantly higher in the stands defoliated less than 50 percent. Also, these stands include more northwest facing sites.

Yellowstone Study Area

As pointed out previously, the Yellowstone area was primarily because of the long term, severe spruce budworm defoliation which has occurred on the area. As a result of this long period of infestation, many of the stands in the area show a pruning effect of the trees where tree growth forms are dominated by epicormic branching. This growth form is more common on the Yellowstone area than on any other study area. The degree of defoliation is also much higher on the Yellowstone area with an average of 66 percent. Although 80 percent of the Yellowstone stands sampled are defoliated at least 50 percent, the variation ranges from no defoliation to total defoliation. Only one stand was found with no defoliation and it is the only stand defoliated less than 20 percent. A range of sites were sampled on the Yellowstone, but because of the general northeast facing trend of the topography, sites of that aspect are most common. South facing stands are rare both because of the topography and the lack of trees on south slopes at the elevations of the study area. For the most part, tree density is higher on the Yellowstone area than other areas, with a corresponding trend for smaller trees. Stands were classified into six major community types on the Yellowstone area (Table 31).

The Pseudotsuga menziesii/Festuca idahoensis/Carex geyeri community type is probably part of the Pseudotsuga menziesii/Festuca idahoensis habitat type. Aspects for this community type range from northeast to southeast with none of the far north or northwest stands that are common elsewhere on the Yellowstone study area. Slopes are mostly quite gentle, averaging only 26 percent which is less than any of the other types on the Yellowstone area. The location of the stands in this type is almost

entirely along ridges or on upper slopes. Average defoliation for the PSME/FEID/CAGE community is a high 74 percent. The maximum level is 96 percent, and although the minimum for the type just exceeds 50 percent, it is the only stand that does not exceed 65 percent.

The Pseudotsuga menziesii/Symphoricarpos albus/Carex geyeri communities on the Yellowstone study area are quite diverse but are grouped together on the basis of the general presence of Symphoicarpos albus, and the lack of Festuca idahoensis and other bunch grasses and Calamagrostis rubescens. The PSME/SYAL/CAGE stands are primarily located on upper slopes and ridges with an undulating microrelief. Slope steepness is varied but generally much steeper than the PSME/FEID/CAGE type. Defoliation for this group of stands ranges from 44 percent to complete defoliation, and averages 69 percent (Table 34).

The Pseudotsuga/Symphoricarpos albus/Festuca idahoensis label is used for this group of stands to maintain continuity throughout this study because these stands are similar in most respects to the same community type on other study areas. Aspects are mostly northwest to northeast or east-southeast. Both topographic positions and slope steepness is varied. Stand defoliation includes levels of 44 to 96 percent, but most are greater than 60 percent with an average of 69 (Table 35.

The Pseudotsuga menziesii/Calamagrostis rubescens/Calamagrostis rubescens community type includes more than one fourth of all the stands sampled on the Yellowstone study area. It is characterized by a dominance of Calamagrostis rubescens and Symphoricarpos albus, and the lack of Festuca idahoensis and associated drier site forbs and grasses. Most of this type are part of the Pseudotsuga menziesii/Calamagrostis rubescens/ Calamagrostis rubescens habitat type. No southwest or southeast stands are

found in this particular community type, and northwest facing stands are restricted to the most northerly aspects. Mid-slope positions are unusual in this particular community type and two of the three ridge located stands are on far north aspects. Canopy coverage is generally more complete for this type than for other communities on the Yellowstone area. Defoliation indices for the PSME/CARU/CARU type have a very broad range from 21 percent to virtually complete defoliation. The average is 59 percent (Table 36).

Similar to the PSME/CARU/CARU community type is the Pseudotsuga menziesii/Linnaea borealis community represented by only four stands which were sampled from three separate parts of the study area. The primary characteristic of this type that separates it from the PSME/CARU/CARU type is the presence of Linnaea borealis. These four stands are part of either the Symphoricarpos albus or the Calamagrostis rubescens phases of the Pseudotsuga menziesii/Linnaea borealis habitat type. The PSME/LIBO type occurs only on far north facing aspects and three are on mid-slope locations. One is associated with a bench-like situation. Elevations are nearly identical for these stands. Average defoliation for the four PSME/LIBO stands is 56 percent; the lowest of any of the types on the Yellowstone area. The range of defoliation values is broad, however, from 25 to 90 percent (Table 37).

The Pseudotsuga menziesii/Physocarpus malvaceus communities are quite distinctive in the Yellowstone study area, occuring on very steep slopes and very specific locations with respect to aspect and elevation. The type occurs principly on east facing aspects, but does occur on north-northeast slopes at lower elevations and on north-northwest slopes at very low elevations. The PSME/PHMA community type consists of two conditions or phases that were combined because of similarities in site and defoliation characteristics. Four stands represent a phase characterized by a dominance

of Symphoricarpos albus and Calamagrostis rubescens. Physocarpus malvaceus occurs only as a scattered sub-dominant. These stands most likely represent the Pseudotsuga menziesii/Physocarpus malvaceus/Calamagrostis rubescens habitat type phase. The remaining stands in this community type are completely dominated by a dense cover of Physocarpus malvaceus. These stands represent the Pseudotsuga menziesii/Physocarpus malveceus/Physocarpus malvaceus habitat type phase. Defoliation for the PSME/PHMA type averages a high 73 percent ranging primarily from 62 to 84 percent (Table 38).

In comparing the community types against each other using analysis of variance and Duncan's multiple range test, the PSME/CARU/CARU and the PSME/LIBO communities have much lower average defoliation levels than any of the other community types. This difference is significant with respect to all the other community types on the study area in the case of the PSME/LIBO type. In the case of the PSME/CARU/CARU type, the difference is significant from all other types except for the PSME/SYAL/FEID type. The PSME/PHMA and PSME/FEID/CAGE types have the highest average percent defoliation, both at about 73%.

For the other variables related to defoliation on the Yellowstone area, the heavily defoliated PSME/PHMA community type is distinctive as it is significantly different than all of the other community types on the Yellowstone in having the steepest slopes and the highest tree densities. The PSME/FEID/CAGE type is also heavily defoliated and is distinctive with the lowest canopy coverage and the highest percentage of southwest stands. The three community types with Calamagrostis rubescens unions tend to occur more frequently on northerly slopes which difference shows up in various aspect functions in the analysis of variance. The highly defoliated PSME/PHMA and PSME/FEID/CAGE

communities consistently show average values either lower or higher than all of the other community types though these differences are not usually significant.

Though there are exceptions within the complex interactions of those factors that appear to influence spruce budworm defoliation, there are some factors that overall show quite consistent relationships within the Yellowstone study area. Defoliation tends to increase as slope aspects shift to the south, with north-northwest sites usually experiencing low defoliation and southwest sites with high defoliation. An exception to this occurs within the PSME/SYAL/FEID community type, but it may be because of an increase in elevation as aspects shift to the south. Exceptions occur elsewhere in the data where high elevations southerly stands are involved since defoliation tends to decrease as elevations increase. In general, as slope increases, defoliation also increases. This relationship probably shows up better here than on the Wall Creek area because steep slopes occur at all elevations and there is a wide variety in steepness of slope; neither of which is the case on the Wall Creek area. Coupled with this is a general increase in tree density and a subsequent decrease in tree size. As a result, defoliation increases with increasing tree density and increases in related variables such as sum of diameters and sometimes total basal area. Defoliation also increases as tree and crown sizes and crown ratios become smaller. This is often related to increases in slope steepness and/or occurrance of south slopes. Again, the PSME/SYAL/CAGE community type is the primary exception to these trends.

Correlation analysis across all stands within the Yellowstone area yields low correlation values for these relationships due to the variation between community types. Elevation particularly looses its identity as a factor

influencing defoliation when the community type categorization is removed. The coefficients for the stand structure variables are at least consistent with the above trends if not high in value. Average diameter shows the highest (negative) correlation with defoliation with the other most commonly related variables having only slightly lower values (Table 32).

Review of the entire data base for the Yellowstone area outside of the community type categories, show very clear trends in some variables. About 35 percent, or all but three of the stands with tree densities of about 1000 trees/hectare or less are defoliated at 70 percent or less. Average tree diameter very definitely averages higher in the less than 65 percent defoliation category as does total tree height, crown lengths, and diameter of average basal area.

Comparison of stands defoliated more than 70 percent to lower defoliation conditions shows that the stands defoliated less than 70 percent have significantly higher averages for average basal area, average diameter, heights, crown length and ratio, and diameter of average basal area. The same stands have higher average density and sum of diameters.

Bear Creek Study Area

The Bear Creek study area was included in this study as a comparison of the east side of the Madison valley against the west side. Tabular data is given in Appendix A, Tables 39 through 45. Because of a general northwest facing contour of the majority of the Bear Creek study area, southwest aspects are rare. Most of the southwest aspects that do occur are devoid of trees. Because of this northerly trend, Pseudotsuga menziesii forms only a narrow band along the base of the mountain range bordered by grasslands below and Pinus contorta associations a short distance upslope. Slopes are

generally steeper than on the Wall Creek area as well. Although tree density tends to be higher on the Bear Creek area, defoliation is generally less than on the Wall Creek area. Average percent defoliation for the entire Bear Creek study area is 43 percent with a maximum of 80 percent and a minimum of 12 percent. Heavy grazing has disturbed many stands on the Bear Creek area so some community types appear quite heterogeneous, but five community types were identified for analysis on the Bear Creek study area (Table 39).

The Pseudotsuga menziesii/Physocarpus malvaceus/Symphoricarpos albus community type is characterized by relatively little undergrowth composed primarily of scattered shrubs, Physocarpus malvaceus and Symphoricarpos albus. Slopes are relatively steep with a variety of topographical settings represented. The PSME/PHMA/SYAL stands are best described by the Pseudotsuga menziesii/Physocarpos malvaceus/Calamagrostis rubescens habitat type. Defoliation in this group shows variation from 14 to 65 percent with an average percentage of 38 percent (Table 41).

The Pseudotsuga menziesii/Physocarpus malvaceus/Physocarpus malvaceus community type is distnictive, having dense stands of Physocarpus malvaceus in the understory. This group of stands is a good example of the Pseudotsuga menziesii/Physocarpus malvaceus/Physocarpus malvaceus habitat type. Aspects inhabited by the PSME/PHMA/PHMA community type vary, but most are to the northwest. Slopes are generally steep and all but one of the stands in this group are located on lower slopes. The one exception is also the only stand to occur on an east facing slope. Elevations are varied also but only two of the six stands much exceed 2000 meters. On the Bear Creek area, the PSME/PHMA/PHMA community type has the highest average level of defoliation of 58 percent with all stands defoliated more than 40 percent. This group of stands includes four of the five most heavily defoliated stands sampled on the study area.

The Pseudotsuga menziesii/Festuca idahoensis/Festuca idahoensis community type is similar to the same type found on other study areas, although Agropyron spicatum is more abundant than on the Wall Creek area. The PSME/FEID/FEID community type is part of the Pseudotsuga menziesii/Festuca idahoensis habitat type. Only four stands are represented in this group, but all four are on aspects facing nearly directly west, and all are on lower slope locations. This indicates that this type is probably one of the driest and/or warmest types on the Bear Creek area. Defoliation is relatively low in this group with an average of 24 percent and a range of 12 to 39 percent.

The Pseudotsuga menziesii/Symphoricarpos albus/Carex geyeri community type is highly varied in its vegetative characteristics. It is separated from the PSME/FEID/FEID type by mainly the lack of Festuca idahoensis and the presence of Symphoricarpos albus which is absent in the Festuca idahoensis type. Heavy grazing in the area has disturbed these communities to the degree where it is difficult to find single common denominators between these stands whereby they can be adequately characterized. The eight stands in this group occur on a variety of topographic locations. Elevations are varied as well. Aspects range from southwest to northwest. The overall average defoliation is 42 percent but the range is from 15 to 66 percent (Table 44).

Three of the four stands representing the Pseudotsuga menziesii/Calamagrostis rubescens/Calamagrostis rubescens community type are marked by the presence of Calamagrostis rubescens, lack bunchgrass, are part of the Pseudotsuga menziesii Calamagrostis rubescens habitat type. These same three stands are at relatively high elevations indicating that this type occurs higher on west slopes due to drier conditions. Also, all of these stands occur on lower slopes or drainages and only on more northerly slopes.

A fourth stand of this community type differed from the other three stands by the presence of Festuca idahoensis, Agropyron caninum, Poa pratensis, Astragalus miser, and several drier site forbs. This fourth stand has a higher level of defoliation than the other three Calamagrostis rubescens stands, and is somewhat similar in composition to the PSME/SYAL/FEID community type on the Wall Creek area. In comparing all four stands, defoliation tends to increase with elevation and is higher on northwest slopes than on northeast slopes. Defoliation tends to decrease as slope increases which again is not related to a change in aspect. The two highest defoliated stands are on lower slopes while the least defoliated stands are in drainages (Table 45).

When community types are compared within the Bear Creek study area, the PSME/PHMA/PHMA community type averages the highest defoliation percentages at 58 percent while the PSME/FEID/CAGE type averages the lowest at 24 percent. These two community types only, are significantly different from each other. All other differences in defoliation are insignificant.

The PSME/PHMA/PHMA type, as the most highly defoliated type, has significantly higher tree densities than both the PSME/FEID/FEID and the PSME/SYAL/CAGE type. At the same time, the PSME/FEID/FEID type has higher crown ratios than most of the other communities. Average basal area and diameter of average basal area both show trees to be largest in the PSME/FEID/FEID and PSME/SYAL/CAGE types and for trees to be smallest in the PSME/PHMA/PHMA and PSME/CARU/CARU types. Defoliation averages highest for the latter pair of communities which agrees well with the relationships found within each community type individually. Aspect relationships show these same two most heavily defoliated community types to occur on the most northerly aspects.

Correlation analysis and review of the entire Bear Creek data base shows defoliation levels to be most closely related to aspect. All but one of the stands on southwest or west aspects with azimuths less than 300 degrees are defoliated less than 40 percent. All of the northwest stands are defoliated more than 40 percent and all but one of the northeast stands is the same. Thus the separation of defoliation is almost total with only one exception. This is in contrast to the Yellowstone and Gallatin areas where the northwest stands are usually among the least defoliated stands. Density tends to be lower in the southwest stands as does average basal area and also average diameter to some degree. Possible these factors are the overriding influence. The high winds mentioned may also be a factor as the north slopes are more protected. Elevation may also be influential, but if so, only for some of the stands. Correlation analysis confirms the above relationships and the results are summarized in appendix A table 40 .

CONCLUSIONS

1. Elk thermal cover in the four study areas is distinctly concentrated in Douglas-Fir stands which occur along the lower margins of continuous forest cover.

2. Spruce budworm damage occurred among all the stands examined with averages ranging from 42% to 70% and with the heaviest damage occurring on the Yellowstone study area.

3. In all four study areas, defoliation was continuous throughout the forest canopy, varying only in degree of defoliation. No large continuously devastating defoliation of elk thermal cover was observed in any of the study areas. Highly defoliated stands resulting in heavy mortality were small, isolated, and frequently in locations where normal elk use was limited.

4. The average degree of defoliation taking place in all four study areas is not considered to alter substantially the value of the thermal cover stand elk. Based on measured temperatures inside and outside of thermal cover, temperature regimes are very similar. What is most important is protection from wind which can substantially alter the microenvironment of the animal. The standing trees on the site, even though defoliated, would provide protection from this element. The opportunity for elk to find higher quality cover than that affected by the specific defoliated stand is great. As previously stated, heavy damage is sporadic.

5. Elk continued to use two of the most heavily defoliated stands on the Wall Creek range as thermal cover. The juxtra-position of these stands to important foraging areas, their topographic location, and structure was an important overriding factor in the continued use of the stands.

6. No correlation was found between the degree of stand damage and increased forage production within the stand.

7. Diets of elk on the Wall Creek winter range are composed primarily of grasses, with estimates ranging from 74% to 84% throughout the winter period.

8. Environmental conditions on the Wall Creek range between thermal cover sites and non-timber sites were very similar in terms of ambient temperatures. The critical difference was in wind flow through the respective sites. Wind flow within cover consistantly averaged less than 1 mph. On comparable topographic sites immediately outside cover, wind flows averaged 4 to 6 mph. On the open valley floor, wind flow averaged between 10 and 15 mph.

9. Nutritional models comparing protein and enrgy intake of cow elk to that required for maintenance and gestation demonstrated a significant deficiency in protein and no deficiency in energy. Probable animal condition going into the winter period and larger available protein sources after the winter period when the fetus is growing at a much more rapid rate likely ameliorate the negative affects of this deficiency. Based on measured temperatures and wind flows on the Wall Creek range during the winter of 1979-80, cow elk maintain adequate body condition to produce a viable calf in late spring or early summer. As long as animals are able to find some escape from winds, have early spring

growth of vegetation available, and are not faced with longterm continuous temperature regimes of -20° F throughout the winter period, and are able to forage adequately throughout the winter, herd productivity as influenced by winter conditions is not likely to change from current levels.

10. Cover loss as experienced through small, disjunct, heavy defoliation of thermal cover stands is not seen as a factor influencing current herd productivity.

11. Degree of defoliation or level of infestation by the spruce budworm appears to be related to both site variables and stand structure variables. Site features help control the local environment of both the spruce budworm population and the trees. That neither tree and stand structure, nor spruce budworm infestations are always dependent on the general site features as measured in this study, as evidenced not only by the variation found within the data, but also by the fact that disturbance of a stand which creates a change in the overstory structure appears to influence budworm populations independent of general macro-site conditions. A good example of this is found on the Wall Creek area. Fires in past history have burned part way across certain slopes with apparently similar site conditions. The burned stands have been replaced by stands of dense, small diameter trees which are much different in structure than the unburned, more mature stands. Distinct differences in the degree of spruce budworm defoliation are evident between the contiguous burned and unburned portions of the slope marked by a sharp break between the two areas of differences in stand structure. Thus, various combinations of site and stand structure

variables that appear to influence the spruce budworm population throughout the study areas, creating a high level of variation that is difficult to interpret or model.

12. In general, spruce budworm defoliation tends to be comparatively high under the following conditions:

    Southward facing slopes

    Low elevations

    Ridges and upper slopes

    Steep slopes

    More open tree canopies

    Dense trees

    Small diameter trees

    Short trees

    Short tree crowns

    Non-dominant status of individual trees

    The relationships of defoliation with height to base of live crown and crown ratios are varied and appear dependent upon other variables. Relationship of defoliation to total basal area does not appear to be as important as is the size of the trees that are included in the basal area value.

    Spruce budworm defoliation generally increases in response to conditions that are more unfavorable for development of Pseudotsuga menziesii usually drier and warmer environmental conditions. This is qualified to apply within certain environmental ranges that the spruce budworm appears restricted to because relatively dry, high elevation stands with apparently cooler environments are mostly uninfested by spruce

budworms. Within the elevation range in question, plant communities are probably more sensitive to differences in moisture, whereas the spruce budworm population may be more sensitive to temperature.

13. Various site conditions are often indicated by understory composition. For example stands with Festuca idahoensis are usually defoliated more than those with Calamagrostis rubescens. As a result, the community type classifications appear as useful indicators of variation in average defoliation potential. However, there is considerable variation in defoliation within each community type with differences in defoliation as related to site and other factors more evident within community types than between types. This would indicate that stand structure is more influential to the spruce budworm population than is the general environment across these communities. This may explain the difficulties involved in using community type classifications alone as indicators of spruce budworm defoliation potential.

In conclusion, community type classifications are valuable indicators of conditions that appear to influence spruce budworm populations, but variation within community types must be considered as well, with particular emphasis on variation in stand structure.

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COOPERATION AND COORDINATION

Involvement was coordinated with personnel from the following agencies and institutions:

A. PNW Forest and Range Experiment Station, LaGrande, Oregon

B. Region 1, Forest Service, FIDM Regional Staff, Missoula, Montana

C. Intermountain Forest and Range Experiment Station, Moscow, Idaho

D. Intermountain Forest and Range Experiment Station, Missoula, Montana

E. Beaverhead National Forest, Forest Staff, Montana

F. Madison Ranger District, Beaverhead National Forest, Montana

G. Galletin National Forest, Forest Staff, Montana

H. Gardiner Ranger District, Galletin National Forest, Montana

I. Montana Fish and Game Department

Cooperative field work was conducted with personnel of Region I Forest Insect and Disease Management Division (FIDM), Forest Service, Missoula, Montana. The principal investigator relied heavily on the knowledge of FIDM concerning selection of additional study areas. FIDM supplied aerial photograph coverage of the Wall Creek elk winter range and outlying areas. The staffs of the Madison Ranger District and of the Beaverhead National Forest pledged cooperation in the study, giving considerable assistance in collection of data and maintenance of instruments over the winter of 1979-80.

Appendix A

Tables 1 - 45

TABLE 1.--Definition of variables appearing in all tables (listed in alphabetical order)

Variable Abbreviation	Definition	Units
ABA	Average tree basal area	Meters^2
ASPECT	Slope aspect azimuth	Degrees
CCOV	Overstory canopy cover	Percent
CL	Average crown length	Meters
COSA	cosine(ASPECT)	
COSA-S	cosine(ASPECT) + (SLOPE/100)	
CR	Average crown ratio	Percent
DABA	Diameter of average tree basal area	Centimeters
DBH	Average tree diameter (measured at breast height)	Centimeters
DC	Crown dominance class: 1 = Isolated 2 = Dominant 3 = Co-dominant 4 = Intermediate 5 = Suppressed	
ELEV	Elevation	Meters
GASPECT	General slope aspect index: 1 = 316° to 45° = North 2 = 46° to 135° = East 3 = 136° to 225° = South 4 = 226° to 315° = West	
HBLC	Average height to base of live crown	Meters
HI	Average total tree height	Meters
LANDFO	Landform class: 1 = Slope 2 = Drainage bottom 3 = Ridge 4 = Bench	

TABLE 1.--(continued)

Variable Abbreviation	Definition	Units
MICR	Microrelief class: 1 = Smooth or straight 3 = Convex 2 = Undulating 4 = Concave	
PDI	Plot or stand defoliation index	Percent
SBA	Total tree basal area	Meters^2/Hectare
SDIA	Sum of tree diameters	Centimeters/Hectare
SINA	sine(ASPECT)	
SINA-S	sine(ASPECT) - (SLOPE/100)	
SLOPE	Slope steepness	Percent
STH	Total tree density	Trees/Hectare
TOPOS	Topographic position class: 1 = Slope - upper 1/3 2 = Slope - middle 1/3 3 = Slope - lower 1/3 4 = Drainage bottom - side 5 = Drainage bottom - bottom 6 = Ridge - top 7 = Ridge - side 8 = Bench - front 9 = Bench - middle 10 = Bench = back	

Table 2. Stand characteristics of the most heavily used thermal cover stands on the Wall Creek study area.[a]

Stand No.	PDI	CCOV	STH	SBA	SDIA	HI	HBLC	CL	CR
905	60	64	823	37	18373	11	4	7.1	64
910	23	57	487	28	12536	12	3	9.0	77
912	38	52	1335	64	32767	11	5	6.0	53
913	69	43	2207	55	37206	9	4	4.1	47
914	58	51	1500	55	31590	15	10	5.0	35
915	37	59	566	73	21528	17	8	9.0	53
919	44	69	3030	56	40565	10	5	4.5	47
921	21	69	904	64	26429	16	8	8.1	50
923	18	69	251	55	13194	18	5	13.1	72
926	41	54	391	55	16115	17	5	11.5	69
927	56	50	640	64	21248	14	7	6.8	47
928	57	62	651	46	19373	12	5	7.5	63
932	42	70	345	64	16641	17	2	14.6	86
941	68	64	1227	55	29161	13	7	5.6	42
956	52	60	607	32	15607	14	8	6.6	45
958	62	62	1030	28	17078	11	8	3.3	28
960	39	61	261	28	9454	16	6	9.8	62

[a] See Table 1 for definition of variables.

Table 3. Stand characteristics of the most heavily used thermal cover stands on the Gallatin study area.[a]

Stand No.	PDI	CCOV	STH	SBA	SDIA	HI	HBLC	CL	CR
1	18	66	637	37	17151	13	5	8.6	65
2	51	64	741	64	24288	16	6	10.7	66
5	39	67	711	32	16699	12	5	7.4	60
6	43	52	1882	41	28969	9	4	5.0	55
7	44	51	276	16	7317	10	2	7.7	79
19	75	55	689	28	15029	11	3	7.6	69
21	56	46	739	28	15423	9	3	6.2	66
3	66	55	447	32	13132	14	5	8.6	65
4	18	75	710	32	15712	12	3	8.8	73
8	60	55	1969	58	33298	14	6	8.5	62
9	57	50	639	37	17199	15	5	10.0	67
10	65	56	1165	37	22001	13	3	9.5	76
11	43	80	1325	32	20508	10	4	6.0	60
12	85	47	1731	28	20507	7	3	4.6	60
13	63	59	645	28	14510	11	3	8.2	74
14	62	58	1714	60	34940	14	5	8.6	62
15	83	50	1131	29	17924	8	2	5.7	67
20	61	57	427	23	10946	14	5	9.1	64
22	48	54	338	28	10745	14	4	9.6	69

[a] See Table 1 for definition of variables.

Table 4. Stand characteristics of the most heavily used thermal cover stands on the Yellowstone study area.

Stand No.	PDI	CCOV	STH	SBA	SDIA	HI	HBLC	CL	CR
60	67	61	2837	51	36921	8	3	4.4	51
62	69	49	1807	55	34646	10	3	7.2	70
71	71	55	1716	61	32277	11	7	4.7	40
57	68	68	1874	64	38427	12	4	7.8	66
55	100	55	1231	73	33622	14	6	8.5	59
56	65	58	562	28	13551	11	4	7.1	63
58	71	67	1442	64	32177	13	6	6.8	52
61	72	48	2073	64	39790	11	6	5.3	48
63	82	70	3011	46	38841	10	5	4.3	42
64	88	64	1812	64	35297	16	10	5.4	34
65	63	80	342	55	15262	17.6	4	13.2	75
66	62	73	1383	55	30624	19	10	9.4	49
67	52	58	868	55	24350	18	7	10.7	29
68	58	75	1006	64	28405	15	5	10.3	67

[a] See Table 1 for definition of variables.

Table 5. Overstory damage in relation to elk use of thermal cover stands.

Study Area	Elk Use Catagory[a]	Average Use within Catagory (Elk Days Use/ac)	Percentage Damage Index ($\bar{x} \pm s$)
Wall Creek	Heavy	122	48 ± 15
	Moderate	45	55 ± 18
	Light	9	59 ± 12
Gallatin	Heavy	117	47 ± 17
	Moderate	45	59 ± 18
	Light	20	76 ± 9
Yellowstone	Heavy	120	69 ± 2
	Moderate	38	71 ± 14
	Light	9	81 ± 10

[a] Use catagories are as follows:
Heavy = > 75 elk day's use/ac.
Moderate = 25-75 elk day's use/ac.
Light = < 75 elk day's use/ac.

Table 6. Average values for production of life form groups in the understory of stands in the Wall Creek, Gallatin, and Yellowstone study areas.

Study Area		Current Year Production (Kg/ha)					
		Trees	Shrubs	Perennial Graminoids	Perennial Forbs	Annuals	TOTAL PRODUCTION
Wall Creek	$\bar{x}$	T[a]	68	104	77	1	250
	s	-	89	91	79	4	184
Gallatin	$\bar{x}$	T	76	120	287	-	483
	s	-	75	106	225	-	314
Yellowstone	$\bar{x}$	T	104	100	120	-	324
	s	-	165	174	175	-	486

[a] T = Trace, < Kg/ha.

Table 7. Understory production, overstory canopy coverage, and overstory damage indices for stands in the Wall Creek study area.

Stand No.	Understory Production (Kg/ha)[a]						Overstory Canopy Coverage	Overstory Damage Index
	Trees	Shrubs	Perennial Graminoids	Perennial Forbs	Annuals	TOTAL		
901	-	-	29.9	9.0	-	38.9	-	-
902	-	31.5	89.6	127.3	16.7	266.8	66	42
903	-	-	88.2	60.6	-	148.7	61	56
904	1.4	176.0	51.3	69.0	-	297.7	63	63
905	-	-	58.0	25.3	3.9	87.1	64	60
906	-	4.0	73.1	42.7	-	119.9	52	66
907	3.7	2.1	117.9	84.4	-	208.1	59	55
908	-	-	149.3	52.5	-	201.8	-	-
909	-	-	130.0	101.6	-	231.6	-	-
910	-	-	74.5	64.1	-	138.6	23	57
911	-	6.4	93.2	78.2	17.9	195.7	-	-
912	-	1.5	40.5	35.7	4.3	80.0	52	38
913	-	40.4	100.2	189.8	-	330.4	43	69
914	-	-	82.7	65.8	-	148.5	51	58
915	-	35.1	22.8	62.9	-	120.8	59	37
916	-	18.7	99.1	50.4	-	168.2	-	-
917	-	30.2	226.1	88.9	-	345.2	53	27
918	0.3	28.4	71.0	74.2	-	174.0	52	36
919	-	183.2	118.5	35.5	-	337.3	69	44
920	-	163.5	167.1	117.0	2.1	449.7	73	18
921	-	19.2	17.2	7.5	-	43.9	69	21
922	-	83.8	155.0	83.5	-	322.9	76	33
923	-	57.8	96.7	14.9	-	169.3	69	18
924	-	83.5	15.7	59.2	-	158.5	61	34
925	-	15.6	99.9	30.6	-	146.1	63	53
926	-	37.8	52.5	40.4	-	130.6	54	41
927	-	1.5	90.0	66.2	-	157.8	50	56
928	-	22.9	167.6	92.0	-	282.5	57	62
929	-	106.2	129.7	98.7	-	334.6	67	38
930	-	49.4	83.6	71.7	-	204.8	75	74

Table 7. Continued

Stand No.	Understory Production (Kg/ha)[a]						Overstory Canopy Coverage	Overstory Damage Index
	Trees	Shrubs	Perennial Graminoids	Perennial Forbs	Annuals	TOTAL		
931	-	86.3	101.9	83.2	-	271.3	56	52
932	-	37.8	63.9	69.2	-	170.9	70	42
933	-	123.6	50.5	7.9	-	182.0	-	-
934	-	6.4	184.0	181.4	3.0	374.8	60	38
935	-	1.0	3.1	0.4	T	3.5	58	59
938	-	-	38.8	7.8	-	46.6	40	28
940	-	20.9	64.0	0.6	-	85.5	64	76
941	-	14.2	100.1	73.0	-	187.3	64	68
944	-	17.6	33.9	29.9	-	81.4	58	62
945	-	188.7	13.9	60.7	-	263.3	56	60
946	-	23.4	38.0	38.1	-	99.5	57	61
947	-	47.6	120.6	60.5	-	228.7	57	76
948	-	52.0	193.9	95.7	-	341.6	58	75
949	-	145.7	90.0	156.0	13.1	404.8	56	60
950	-	294.7	70.8	239.5	-	605.0	54	73
951	-	73.7	144.3	495.6	-	713.7	41	86
952	-	129.5	153.1	208.3	-	490.9	51	73
954	-	178.3	60.1	161.5	-	399.9	56	70
953	-	95.3	286.1	24.9	-	406.3	57	62
955	-	44.8	58.9	14.6	-	118.3	67	58
956	-	104.1	344.2	20.5	-	468.8	60	52
957	-	1.0	17.1	1.9	-	19.9	62	48
958	-	84.0	206.0	17.2	-	307.2	62	62
959	-	67.3	47.8	3.2	-	118.4	63	63
960	-	518.7	149.5	151.5	-	819.6	61	39
961	-	118.0	203.5	100.2	-	421.7	56	64
962	-	177.4	616.4	60.5	-	854.2	63	83

[a] T = Trace amounts, 20.1 Kg/ha.

Table 8. Understory production, overstory canopy coverage, and overstory damage indices for stands in the Galletin study area.

Stand No.	Plot No.	Understory Production (Kg/ha)[a]						Overstory[b] Canopy Coverage	Overstory[c] Damage Index
		Trees	Shrubs	Perennial Graminoids	Perennial Forbs	Annuals	TOTAL		
1	1	2.4	51.7	21.9	60.4	0.7	137.0	66	18
2	1	1.3	89.6	58.1	160.3	-	309.4	64	51
3	1	-	77.2	91.3	102.3	-	270.9	55	66
4	1	-	67.7	12.7	124.3	-	204.8	75	18
5	1	-	38.7	31.1	227.2	-	297.0	67	39
6	1	-	14.0	106.6	510.2	-	630.8	52	43
7	1	-	224.7	317.8	662.3	-	1204.7	51	44
8	1	-	57.7	60.9	242.3	-	360.9	55	60
9	1	-	33.4	65.5	295.1	-	394.0	50	57
10	1	-	271.9	90.9	265.0	-	627.9	56	65
11	1	-	26.0	37.4	49.5	-	112.9	80	43
12	1	-	165.7	61.7	725.9	-	953.3	47	85
13	1	-	84.7	117.7	324.1	-	526.6	59	63
14	1	-	-	178.4	218.0	-	396.4	58	62
15	1	-	13.8	102.0	118.8	-	234.6	50	83
16	1	-	32.0	323.7	803.2	-	1158.8	56	86
17	1	-	165.2	29.1	112.5	-	306.8	52	69
18	1	-	47.6	118.5	245.4	-	411.6	63	73
19	1	-	-	192.3	269.2	-	461.5	55	75
20	1	4.0	150.1	7.7	111.3	-	273.1	57	61
21	1	-	68.1	282.9	582.4	-	933.4	46	56
22	1	-	-	338.2	102.9	-	441.2	54	48

a T = Trace amounts, 20.1 Kg/ha.
b
c

Table 9 . Understory production, overstory canopy coverage, and overstory damage indices for stands in the Yellowstone study area

Stand No.	Plot No.	Understory Production (Kg/ha)[a]						Overstory[b] Canopy Coverage	Overstory[c] Damage Index
		Trees	Shrubs	Perennial Graminoids	Perennial Forbs	Annuals	TOTAL		
57	1	-	6.7	19.1	-	-	25.7	68	68
58	1	1.1	-	12.9	-	-	14.0	67	71
59	1	-	186.4	14.0	54.1	-	254.6	66	81
60	1	0.5	7.4	95.0	63.8	-	166.6	61	67
61	1	-	30.4	18.5	96.5	-	145.5	48	72
62	1	2.5	4.7	9.8	20.0	-	37.0	49	69
63	1	-	173.0	41.9	102.0	-	316.9	70	82
64	1	-	89.8	12.7	293.6	-	396.2	64	88
65	1	0.7	-	50.3	34.0	-	85.1	80	63
66	1	-	98.2	13.7	34.3	-	146.2	73	62
67	1	2.7	122.4	1.9	44.2	-	171.2	58	52
68	1	-	8.0	245.4	173.9	-	427.4	75	58
69	1	-	91.8	217.4	99.6	-	408.7	62	63
70	1	-	630.7	641.2	664.8	-	1936.7	57	84
71	1	-	-	-	-	-	-	55	71
72	1	-	-	-	-	-	-		

[a] T = Trace amounts, 20.1 Kg/ha.

Table 10. Average Composition (%) of elk diets on Wall Creek Study Area for 1979-1980 winter period.

Species Lifeform Group	Percentage Composition by Month				
	Dec. 1979	Jan. 1980	Feb. 1980	Mar. 1980	April 1980
Trees	--	--	--	--	--
Shrubs	15	15	14	14	14
Graminoids	74	81	82	83	82
Forbs	11	4	4	3	4

Table 11. Quality of recontstructed elk diets for the winter of 1979-80 on the Wall Creek Game Range.

Diet	Digestible Dry Matter (%)	Crude Protein (%)	Digestible Protein (%)	Gross Energy (cal/gm)	Digestible Energy (cal/gm)
Dec. 1979	50.9	5.8	3.0	4356	1891
Jan. 1980	49.3	5.3	2.6	4358	1807
Feb. 1980	48.0	4.9	2.2	4348	1741
Mar. 1980	48.3	5.0	2.3	4150	1756
April 1980	47.3	4.7	2.0	4187	1705

TABLE 12.--Summary statistics for the Wall Creek study area

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	161	49.80303856	22.48487258	8018.2892084	0	96.85413271
ELEV	161	2060.86652422	102.42327920	31799.5104000	1843.12560000	2353.00000000
SLOPE	161	32.87577640	10.81535816	5293.0000000	11.00000000	64.00000000
STH	161	1192.67065152	1445.55436605	92019.9748942	173.29109501	14640.66069196
SBA	161	42.56965725	15.13608330	6853.7148171	11.16230779	94.63847830
SDIA	161	21586.64987565	10921.04085340	375450.6299792	5048.13434467	74988.10581996
ABA	161	0.05868337	0.04014755	9.4480224	0.00192308	0.21939722
DBH	161	24.33985235	9.14003636	3918.7162281	3.50445458	52.54106060
HI	161	12.81663884	3.65022889	2063.4788526	3.69151548	23.64470521
HBLC	161	6.66843016	2.71408766	1073.6172565	0.39904890	13.95659535
CL	161	6.14820867	2.55344668	989.8615961	1.40048336	14.64746827
CR	161	47.58007561	14.98665898	7660.3921737	13.21961034	89.50534387
DABA	161	26.32390161	9.01864715	4238.1481585	5.03557942	53.78564738
ASPECT	161	84.68322981	92.90360746	13634.0000000	0	359.00000000
GASPECT	161	1.55279503	0.52321866	250.0000000	1.00000000	3.00000000
COSA	161	0.56372849	0.40009395	90.7602865	-0.90630339	1.00000000
COSA-S	161	0.89248625	0.41340678	143.6902865	-0.55630339	1.50619262
SINA	161	0.59868096	0.40711157	96.3876342	-0.57359432	1.00000000
SINA-S	161	0.26992319	0.42941109	43.4576342	-1.19359432	0.86619420
CCOV	161	53.79968944	10.98030267	8661.7500000	25.00000000	85.25000000

[a]See Table 1 for definitions.

TABLE 14.--Summary statistics for the PSME/FEID/FEID community type -- Wall Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	10	59.64275215	26.20784830	596.42752148	23.02808995	96.85413271
ELEV	10	1918.82440000	31.30512582	9188.24400000	1876.04400000	1980.00000000
SLOPE	10	28.20000000	7.19258878	282.00000000	12.00000000	38.00000000
STH	10	1471.46760424	937.94550355	4714.67604237	190.81119028	3156.76580130
SBA	10	32.26426706	12.51011153	322.64267055	11.47841073	50.62969925
SDIA	10	21186.00307664	8955.06862474	21860.03076643	5048.13434467	35594.61335456
ABA	10	0.02981230	0.01628545	0.29812298	0.00725524	0.06015586
DBH	10	17.22340233	5.66558113	172.23402333	8.79465007	26.45617554
HI	10	8.59194495	1.88302433	85.91944950	6.46119921	12.05430859
HBLC	10	3.91983941	1.02109094	39.19839415	1.91677813	5.22537957
CL	10	4.67210554	1.73038279	46.72105535	1.95554809	7.05514738
CR	10	51.84669097	13.68053110	518.46690969	28.93052981	77.27805589
DABA	10	19.12789649	5.49931506	191.27896492	9.78084974	28.16370573
ASPECT	10	77.60000000	45.81169186	776.00000000	10.00000000	145.00000000
GASPECT	10	1.80000000	0.63245553	18.00000000	1.00000000	3.00000000
COSA	10	0.17010884	0.68179602	1.70108838	-0.81914646	0.98480787
COSA-S	10	0.45210884	0.69508544	4.52108838	-0.53914646	1.22480787
SINA	10	0.71402822	0.21823903	7.14028222	0.17364752	0.90631105
SINA-S	10	0.43202822	0.22309520	4.32028222	-0.06635248	0.78631105
CCOV	10	49.95000000	7.47384328	499.50000000	40.00000000	60.50000000

[a]See Table 1 for definitions.

TABLE 15.--Summary statistics for the PSME/FEID/CAGE community type -- Wall Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	38	47.73467857	18.73826241	1813.91778554	12.50000000	85.75305227
ELEV	38	2043.72181053	81.04618567	7661.42880000	1919.00000000	2220.00000000
SLOPE	38	30.71052632	8.65216078	1167.00000000	16.00000000	55.00000000
STH	38	787.97364339	588.61170849	9942.99844866	173.29109501	2714.77088525
SBA	38	41.56786504	15.78157803	1579.57887148	13.55781848	73.46182865
SDIA	38	18268.41161361	7968.16315866	64199.64131727	6700.60536857	38022.84411598
ABA	38	0.07317129	0.04345444	2.78050885	0.00995699	0.18621298
DBH	38	27.91313179	9.13470738	1060.69900792	8.93434567	48.20791871
HI	38	12.73042954	3.29701923	483.75632245	4.53401953	20.85680320
HBLC	38	5.39924607	2.17425469	205.17135047	1.28096225	9.13578264
CL	38	7.33118347	2.73371481	278.58497198	3.17613914	14.64746827
CR	38	56.85428252	14.36430464	2160.46273593	24.43272489	86.21907183
DABA	38	29.72695683	9.12752462	1129.62435935	11.45816019	49.55138686
ASPECT	38	98.05263158	116.59862949	3726.00000000	0	348.00000000
GASPECT	38	1.39473684	0.49535538	53.00000000	1.00000000	2.00000000
COSA	38	0.69691609	0.29454688	26.48281153	-0.08714939	1.00000000
COSA-S	38	1.00402136	0.29695373	38.15281153	0.30716143	1.35718441
SINA	38	0.44272867	0.49004500	16.82368939	-0.57359432	0.99619525
SINA-S	38	0.13562340	0.49299752	5.15368939	-0.91359432	0.77619420
CCOV	38	53.89473684	11.55401995	2048.00000000	25.00000000	73.25000000

[a]See Table 1 for definitions.

TABLE 16.--Summary statistics for the PSME/SYAL/CAGE community type -- Wall Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	15	52.37456439	24.53781060	785.61846586	12.50000000	91.60164471
ELEV	15	2076.85728000	85.02502288	1152.85920000	1940.00000000	2283.00000000
SLOPE	15	27.13333333	7.76316087	407.00000000	16.00000000	41.00000000
STH	15	916.03699504	618.69335034	3740.55492565	235.20904119	2805.37653831
SBA	15	44.85618479	18.00793028	672.84277188	11.16230779	73.46182865
SDIA	15	19647.26562295	7070.89128352	24708.98434426	7210.51272863	33642.42160969
ABA	15	0.06702302	0.03833101	1.00534529	0.00397890	0.14657942
DBH	15	26.16318487	9.69351358	392.44777311	6.32296569	43.04295959
HI	15	13.37485024	4.60002332	200.62275367	3.69151548	19.11936552
HBLC	15	7.03274073	3.76494060	105.49111099	0.39904890	13.05833211
CL	15	6.34210951	2.28327058	95.13164268	3.29246658	11.38732220
CR	15	50.31494676	17.58302380	754.72420133	26.43997496	89.50534387
DABA	15	28.33251769	9.31650509	424.98776531	7.24322964	43.96300200
ASPECT	15	53.26666667	37.07611219	799.00000000	5.00000000	155.00000000
GASPECT	15	1.60000000	0.63245553	24.00000000	1.00000000	3.00000000
COSA	15	0.53099057	0.48989490	7.96485851	-0.90630339	0.99619473
COSA-S	15	0.80232390	0.47818416	12.03485851	-0.55630339	1.31630850
SINA	15	0.64232400	0.29545066	9.63485993	0.08715541	0.99026730
SINA-S	15	0.37099066	0.29994121	5.56485993	-0.09284459	0.79026730
CCOV	15	55.90000000	11.80715582	838.50000000	25.00000000	75.25000000

[a]See Table 1 for definitions.

TABLE 17.--Summary statistics for the PSME/SYAL/FEID community type -- Wall Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	37	55.39334637	19.05582772	2049.55381558	14.63487519	91.22617008
ELEV	37	2024.54886486	106.01972669	4908.30800000	1843.12560000	2278.00000000
SLOPE	37	33.21621622	10.08611569	1229.00000000	19.00000000	64.00000000
STH	37	1064.64637563	1011.03673543	9391.91589827	197.41843688	5893.43298761
SBA	37	39.61578863	13.29879870	1465.78417926	18.36545716	64.27910007
SDIA	37	20692.25861805	10289.65858968	75613.56886774	8242.60994087	50560.88209583
ABA	37	0.05400439	0.03086464	1.99816235	0.00630019	0.16279913
DBH	37	23.93411177	7.33194274	885.56213562	8.57919013	44.75256729
HI	37	12.99625018	2.74923004	480.86125661	6.63639151	20.27347673
HBLC	37	6.58488279	1.95846841	243.64066336	2.89525830	11.90311701
CL	37	6.41136739	2.20734586	237.22059325	2.06127407	11.63998845
CR	37	48.81589603	12.71318371	1806.18815302	28.80168224	73.43037472
DABA	37	25.71740718	7.21847796	951.54406562	9.11438886	46.33155532
ASPECT	37	112.94594595	118.07811584	4179.00000000	8.00000000	355.00000000
GASPECT	37	1.56756757	0.50224720	58.00000000	1.00000000	2.00000000
COSA	37	0.56760724	0.40277537	21.00146786	-0.64278092	0.99619262
COSA-S	37	0.89976940	0.39743465	33.29146786	-0.00278092	1.50619262
SINA	37	0.57089986	0.44658957	21.12329470	-0.42263865	1.00000000
SINA-S	37	0.23873769	0.46379313	8.83329470	-0.82263865	0.80619525
CCOV	37	55.37162162	11.31932676	2048.75000000	35.00000000	85.25000000

[a]See Table 1 for definitions.

TABLE 18.--Summary statistics for the PSME/SYAL/CARU community type -- Wall Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	19	56.64715376	20.56521605	1076.29592143	18.00000000	93.34968342
ELEV	19	2081.19317895	58.73913353	9542.67040000	2000.09760000	2245.00000000
SLOPE	19	28.63157895	10.94537206	544.00000000	11.00000000	52.00000000
STH	19	1019.45636064	757.24859683	9369.67085213	251.12611225	3029.62884378
SBA	19	49.77171673	13.47350620	945.66261781	28.97877034	73.46182865
SDIA	19	21305.03486680	8197.38425707	44795.66246920	11712.20677596	40565.08801714
ABA	19	0.07652457	0.05585872	1.45396674	0.01849333	0.21939722
DBH	19	27.26262940	11.81184705	517.98995853	12.48150484	52.54106060
HI	19	13.66940672	4.65767605	259.71872776	6.44505942	23.64470521
HBLC	19	6.86112425	2.83200873	130.36136082	2.50692822	12.17567867
CL	19	6.80828247	2.99358868	129.35736694	2.55983647	13.11538756
CR	19	48.55866574	12.80488724	922.61464906	31.08921965	71.58428278
DABA	19	29.91056946	10.98812811	568.30081981	15.61559169	53.78564738
ASPECT	19	59.94736842	18.81038036	1139.00000000	12.00000000	85.00000000
GASPECT	19	1.78947368	0.41885391	34.00000000	1.00000000	2.00000000
COSA	19	0.47191635	0.24980955	8.96641065	0.08716143	0.97814777
COSA-S	19	0.75823214	0.26660155	14.40641065	0.38791682	1.24814777
SINA	19	0.82496315	0.19924828	15.67429988	0.20791090	0.99619420
SINA-S	19	0.53864736	0.21642266	10.23429988	-0.06208910	0.79814651
CCOV	19	55.48684211	9.67042803	1054.25000000	40.00000000	76.00000000

[a]See Table 1 for definitions.

TABLE 19.--Summary statistics for the PSME/CARU/CARU community type -- Wall Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	7	62.74658730	12.39912475	439.22611112	40.21220455	82.70650425
ELEV	7	2075.42982857	93.17920249	4528.00880000	1977.84720000	2237.00000000
SLOPE	7	35.85714286	11.65373433	251.00000000	13.00000000	48.00000000
STH	7	1037.45842572	676.91377574	7262.20898006	419.35557736	2068.82271484
SBA	7	36.07500514	11.98119464	252.52503598	18.36545716	55.09637149
SDIA	7	20322.40124288	10464.52029111	12256.80870016	9467.20669141	36984.37339650
ABA	7	0.04465396	0.02470787	0.31257770	0.02475366	0.08758895
DBH	7	21.69255123	5.31403018	151.84785864	16.58902084	29.19073425
HI	7	13.11163131	1.91482846	91.78141918	10.85445355	15.92259113
HBLC	7	8.39646362	2.33176296	58.77524534	5.96987865	12.42869965
CL	7	4.71516769	1.84202732	33.00617384	2.51104338	7.37845654
CR	7	35.47099339	12.96275064	248.29695373	18.78407967	50.50809578
DABA	7	23.55463145	6.29545820	164.88242012	18.06635460	33.98407830
ASPECT	7	92.14285714	120.07279538	645.00000000	16.00000000	359.00000000
GASPECT	7	1.28571429	0.48795004	9.00000000	1.00000000	2.00000000
COSA	7	0.67297451	0.34142724	4.71082159	0.08716143	0.99984727
COSA-S	7	1.03154594	0.43243608	7.22082159	0.21716143	1.39126199
SINA	7	0.57583872	0.36723519	4.03087105	-0.01747651	0.99619420
SINA-S	7	0.21726729	0.43598285	1.52087105	-0.39747651	0.86619420
CCOV	7	54.46428571	11.07213899	381.25000000	40.00000000	66.00000000

[a]See Table 1 for definitions.

TABLE 20.--Summary statistics for the PSME/CARU/PAMY community type -- Wall Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	29	41.21650577	22.43366060	1195.27866734	12.50000000	94.17212983
ELEV	29	2106.10314483	70.50450491	1076.99120000	1986.99120000	2243.00000000
SLOPE	29	39.82758621	12.85654076	1155.00000000	15.00000000	62.00000000
STH	29	1919.94826377	2784.99252012	5678.49964919	212.68009870	14640.66069196
SBA	29	44.92639525	12.78219223	1302.86546230	22.95682145	73.46182865
SDIA	29	26674.27811684	14567.99218990	73554.06538828	8453.40361290	74988.10581996
ABA	29	0.04686670	0.03440153	1.35913432	0.00192308	0.15111687
DBH	29	21.39447822	8.42696022	620.43986844	3.50445458	41.79972125
HI	29	13.44467536	3.84507652	389.89558549	3.86712855	21.75014865
HBLC	29	8.58605382	2.55304582	248.99556065	2.16022228	13.95659535
CL	29	4.85862155	2.16326681	140.90002483	1.40048336	11.78728262
CR	29	34.91692808	9.67296985	1012.59091427	13.21961034	54.43722135
DABA	29	23.40372193	8.52890689	678.70793587	5.03557942	44.63826513
ASPECT	29	70.68965517	77.27183161	2050.00000000	5.00000000	335.00000000
GASPECT	29	1.51724138	0.50854763	44.00000000	1.00000000	2.00000000
COSA	29	0.57136713	0.38821543	16.56964681	-0.17364156	0.99619473
COSA-S	29	0.96964299	0.40743439	28.11964681	-0.02364156	1.46630850
SINA	29	0.60206889	0.41406576	17.45999786	-0.57359432	1.00000000
SINA-S	29	0.20379303	0.46707402	5.90999786	-1.19359432	0.83480892
CCOV	29	47.98275862	9.15002221	1391.50000000	30.00000000	71.50000000

[a]See Table 1 for definitions.

TABLE 21.--Summary statistics for the high elevation group of stands on the Wall Creek study area

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	6	10.32848667	18.18093360	61.97092002	0	44.63463746
ELEV	6	2290.16666667	59.45222171	3741.00000000	2183.00000000	2353.00000000
SLOPE	6	43.00000000	3.40587727	258.00000000	39.00000000	47.00000000
STH	6	1986.57501632	1586.62108766	1919.45009790	526.02799683	4872.69800725
SBA	6	51.96886797	24.28399785	311.81320784	25.25250360	94.63847830
SDIA	6	31410.31135430	19200.43949449	18461.86812582	18681.00357137	68943.75615409
ABA	6	0.04003403	0.03488330	0.24020418	0.01473623	0.10474038
DBH	6	19.58260042	9.20759308	117.49560252	12.76061272	35.51332569
HI	6	11.82055632	4.15943592	70.92333790	8.26370294	17.62466836
HBLC	6	6.99726179	2.46492229	41.98357072	4.58398027	10.47103900
CL	6	4.82329453	1.95753667	28.93976718	3.28656169	8.28262006
CR	6	39.50794277	6.09953890	237.04765662	31.11925443	46.87288516
DABA	6	21.47030458	8.95996986	128.82182749	13.93940051	37.16275544
ASPECT	6	53.33333333	22.73030283	320.00000000	20.00000000	90.00000000
GASPECT	6	1.66666667	0.51639778	10.00000000	1.00000000	2.00000000
COSA	6	0.56053020	0.31306153	3.36318118	.000006044750775	0.93969308
COSA-S	6	0.99053020	0.33246794	5.94318118	0.41000604	1.38969308
SINA	6	0.75005652	0.22328864	4.50033912	0.34201888	1.00000000
SINA-S	6	0.32005652	0.24346286	1.92033912	-0.10798112	0.59000000
CCOV	6	66.66666667	6.05530071	400.00000000	60.00000000	75.00000000

[a]See Table 1 for definitions.

TABLE 21.--Correlation matrix of site, stand, and defoliation variables[a] on the Wall Creek study area

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 161

	PDI	ELEV	SLOPE	STH	SBA	SDIA	ABA	DBH	HI	HBLC	CL	CR	DABA
PDI	1.00000	-0.40201	-0.09494	0.20540	-0.27151	0.03438	-0.33652	-0.36835	-0.38235	-0.27367	-0.25569	0.02396	-0.36637
	0.0000	0.0001	0.2310	0.0090	0.0005	0.6651	0.0001	0.0001	0.0001	0.0004	0.0011	0.7629	0.0001
ELEV	-0.40201	1.00000	0.33045	-0.00623	0.24496	0.08298	0.16098	0.14318	0.17184	0.13937	0.09751	-0.03136	0.15456
	0.0001	0.0000	0.0001	0.9374	0.0017	0.2954	0.0414	0.0700	0.0293	0.0779	0.2185	0.6929	0.0503
SLOPE	-0.09494	0.33045	1.00000	0.29140	0.10831	0.35355	-0.30273	-0.29676	-0.12562	0.11957	-0.30667	-0.32702	-0.31378
	0.2310	0.0001	0.0000	0.0002	0.1715	0.0001	0.0001	0.0001	0.1123	0.1309	0.0001	0.0001	0.0001
ASPECT	0.06047	-0.13433	0.08016	0.07935	0.02859	0.13911	-0.09001	-0.09056	-0.12500	-0.13038	-0.04011	0.04093	-0.10393
	0.4461	0.0893	0.3121	0.3170	0.7189	0.0784	0.2562	0.2533	0.1141	0.0992	0.6135	0.6062	0.1895
GASPECT	0.01258	0.31900	-0.05295	-0.20095	-0.07818	-0.23467	0.15952	0.15783	0.03655	-0.11626	0.17582	0.18547	0.17086
	0.8741	0.0001	0.5047	0.0106	0.3242	0.0027	0.0432	0.0456	0.6453	0.1419	0.0257	0.0185	0.0302
COSA	-0.04806	-0.23743	-0.01002	0.12938	0.08240	0.15672	-0.07860	-0.06877	0.02993	0.10068	-0.06423	-0.11312	-0.08066
	0.5449	0.0024	0.8996	0.1019	0.2987	0.0471	0.3217	0.3861	0.7063	0.2038	0.4182	0.1531	0.3091
COSA-S	-0.07135	-0.14334	0.25192	0.20145	0.10808	0.24416	-0.15527	-0.14419	-0.00390	0.12872	-0.14239	-0.19503	-0.16015
	0.3684	0.0697	0.0013	0.0104	0.1723	0.0018	0.0492	0.0680	0.9608	0.1037	0.0716	0.0132	0.0424
SINA	0.02874	0.32751	-0.07900	-0.19201	-0.02682	-0.21882	0.17394	0.16872	0.13019	0.02061	0.16420	0.11394	0.18620
	0.7174	0.0001	0.3192	0.0147	0.7356	0.0053	0.0273	0.0324	0.0998	0.7953	0.0374	0.1501	0.0180
SINA-S	0.05116	0.22727	-0.32676	-0.25544	-0.05271	-0.29651	0.24116	0.23470	0.15507	-0.01058	0.23291	0.19039	0.25556
	0.5193	0.0037	0.0001	0.0011	0.5067	0.0001	0.0021	0.0027	0.0495	0.8941	0.0029	0.0156	0.0011
CCOV	-0.28269	0.12537	-0.02885	-0.03481	0.28703	0.03064	0.26117	0.28026	0.25111	0.00552	0.35311	0.18667	0.27722
	0.0003	0.1130	0.7164	0.6611	0.0002	0.6996	0.0008	0.0003	0.0013	0.9446	0.0001	0.0177	0.0004

[a]See Table 1 for definitions.

TABLE 22.--Summary statistics for the Gallatin study area

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	71	50.36898081	26.28495966	3576.1976373	0	100.00000000
ELEV	71	2048.53583099	78.34656937	45446.0440000	1876.04400000	2320.00000000
SLOPE	71	33.87323944	12.23919883	2405.0000000	7.00000000	58.00000000
STH	71	1101.54977523	633.99236359	78210.0340410	265.00335155	2772.59918916
SBA	71	44.16456567	17.39631054	3135.6841626	16.06977502	98.87225886
SDIA	71	21856.21186706	8015.13549622	151791.0425612	7316.95154836	43426.94677221
ABA	71	0.05166526	0.03121460	3.6682335	0.01153480	0.16973988
DBH	71	23.05055605	7.46133803	1636.5894797	9.83197102	43.79957683
HI	71	13.73070575	4.78902480	974.8801080	6.09361534	27.51647085
HBLC	71	5.91020355	3.23257724	419.6244520	2.07016002	18.82847622
CL	71	7.82050220	2.54152684	555.2556560	3.03375361	15.17392231
CR	71	57.46089332	11.61868577	4079.7234254	30.54918629	78.58392348
DABA	71	25.07719574	7.28853276	1780.4808977	12.33263417	47.30889266
ASPECT	71	181.14084507	99.38644572	12861.0000000	10.00000000	355.00000000
GASPECT	71	2.70422535	1.13885113	192.0000000	1.00000000	4.00000000
COSA	71	-0.02844754	0.65032667	-2.0197752	-0.99756491	0.99619262
COSA-S	71	0.31028486	0.67851436	22.0302248	-0.73452320	1.44480367
SINA	71	-0.02468403	0.76806387	-1.7525659	-1.00000000	0.99452131
SINA-S	71	-0.36341642	0.78341615	-25.8025659	-1.55000000	0.85592452
CCOV	71	54.58802817	8.69996907	3875.7500000	30.00000000	80.00000000

[a]See Table 1 for definitions.

TABLE 23.--Correlation matrix of site, stand, and defoliation variables[a] on the Gallatin study area

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 71

	PDI	ELEV	SLOPE	STH	SBA	SDIA	ABA	DBH	HI	HBLC	CL	CR	DABA
PDI	1.00000	-0.31022	0.03815	0.17505	-0.33629	-0.11090	-0.29574	-0.33320	-0.43853	-0.39529	-0.32355	0.09601	-0.33701
	0.0000	0.0085	0.7521	0.1443	0.0041	0.3572	0.0123	0.0045	0.0001	0.0006	0.0059	0.4257	0.0041
ELEV	-0.31022	1.00000	-0.02555	0.11080	0.20304	0.19056	-0.00832	-0.02147	0.06686	0.02439	0.09496	0.09651	-0.00288
	0.0085	0.0000	0.8325	0.3577	0.0895	0.1114	0.9451	0.8589	0.5796	0.8400	0.4309	0.4234	0.9810
SLOPE	0.03815	-0.02555	1.00000	0.21006	-0.08353	0.05870	-0.08927	-0.11669	-0.01739	0.14067	-0.21169	-0.33178	-0.12460
	0.7521	0.8325	0.0000	0.0787	0.4886	0.6268	0.4591	0.3325	0.8856	0.2420	0.0764	0.0047	0.3005
ASPECT	-0.08039	-0.11418	0.04447	-0.00093	0.19098	0.06629	0.16551	0.13344	0.02181	-0.01861	0.06477	0.02211	0.15114
	0.5051	0.3431	0.7127	0.9939	0.1106	0.5829	0.1678	0.2673	0.8567	0.8776	0.5915	0.8548	0.2083
GASPECT	0.20819	-0.12159	-0.12059	-0.07430	0.02593	-0.07480	0.13747	0.10346	-0.12943	-0.25536	0.08091	0.26251	0.11623
	0.0815	0.3124	0.3165	0.5380	0.8301	0.5353	0.2530	0.3906	0.2820	0.0316	0.5024	0.0270	0.3344
COSA	-0.25961	-0.26468	0.14120	-0.04088	0.24581	0.11973	0.21508	0.22353	0.45741	0.52975	0.18812	-0.39826	0.22916
	0.0288	0.0257	0.2402	0.7350	0.0388	0.3200	0.0717	0.0610	0.0001	0.0001	0.1162	0.0006	0.0546
COSA-S	-0.24195	-0.25829	0.31571	-0.00129	0.22053	0.12535	0.19004	0.19319	0.43527	0.53311	0.14212	-0.44156	0.19716
	0.0421	0.0296	0.0073	0.9915	0.0646	0.2976	0.1124	0.1065	0.0001	0.0001	0.2371	0.0001	0.0993
SINA	-0.01750	0.13052	-0.04701	0.02511	-0.14328	-0.02366	-0.19225	-0.16608	-0.05656	0.02636	-0.14010	-0.06975	-0.17871
	0.8849	0.2780	0.6970	0.8354	0.2333	0.8448	0.1082	0.1663	0.6394	0.8273	0.2439	0.5632	0.1359
SINA-S	-0.02311	0.13195	-0.20232	-0.00820	-0.12742	-0.03236	-0.17453	-0.14459	-0.05273	0.00387	-0.10428	-0.01655	-0.15574
	0.8483	0.2727	0.0906	0.9459	0.2896	0.7888	0.1455	0.2289	0.6623	0.9745	0.3868	0.8910	0.1947
CCOV	-0.47043	0.18298	-0.18115	0.03127	0.23843	0.17833	-0.00115	0.02595	0.11720	0.09390	0.10141	0.02686	0.02721
	0.0001	0.1267	0.1306	0.7957	0.0452	0.1368	0.9924	0.8299	0.3304	0.4360	0.4001	0.8241	0.8218

[a]See Table 1 for definitions.

TABLE 24--Summary statistics for the PSME/FEID/AGSP community type -- Gallatin

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	23	64.08266147	18.68737195	1473.90121378	12.50000000	86.71686751
ELEV	23	2029.23377391	68.59750728	6672.37680000	1876.04400000	2152.00000000
SLOPE	23	34.04347826	12.64004553	783.00000000	18.00000000	58.00000000
STII	23	1116.89577025	647.64811325	5688.60271582	265.00335155	2772.59918916
SBA	23	37.01694434	13.29815538	851.38971975	22.95682145	64.27910007
SDIA	23	20139.14850108	6511.76393205	43200.41552488	9535.25863972	33305.17789040
ABA	23	0.04291161	0.02410770	0.98696706	0.01153480	0.10395410
DBH	23	21.14475032	7.09607107	486.32925735	10.06399838	35.98165300
HI	23	10.84583574	3.11922740	249.45422207	6.55132061	16.21612219
HBLC	23	3.86691472	1.19678250	88.93903849	2.27414004	5.95759312
CL	23	6.97892103	2.30628413	160.51518358	3.70497174	10.64778340
CR	23	62.18302187	8.77085452	1430.20950294	42.58256162	73.53750201
DAHA	23	22.90391092	6.56525321	526.78995108	12.33263417	37.02300416
ASPECT	23	180.26086957	65.70195610	4146.00000000	84.00000000	278.00000000
GASPECT	23	2.95652174	0.82452526	68.00000000	2.00000000	4.00000000
COSA	23	-0.46293512	0.35277013	-10.64750767	-0.93968895	0.13915461
COSA-S	23	-0.12250033	0.37647106	-2.81750767	-0.68968895	0.61915461
SINA	23	0.01897441	0.83461437	0.43641141	-1.00000000	0.99452131
SINA-S	23	-0.32146037	0.88311112	-7.39358859	-1.55000000	0.81452131
CCOV	23	52.02173913	8.43151321	1196.50000000	30.00000000	64.00000000

[a]See Table 1 for definitions.

TABLE 25.--Summary statistics for the PSME/FEID/FEID community type -- Gallatin

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	10	36.40083797	20.97213827	364.00837966	14.51905223	81.81646423
ELEV	10	2044.64736000	105.49977741	0446.47360000	1902.86640000	2197.91280000
SLOPE	10	25.50000000	8.86002257	255.00000000	11.00000000	39.00000000
STH	10	827.77685621	471.68469351	8277.76856213	275.50361937	1882.03625752
SBA	10	31.93492023	6.73056412	319.34920229	16.06977502	41.44697067
SDIA	10	16988.90001036	5725.23553184	19889.00010362	7316.95154836	28968.66787587
ABA	10	0.04632266	0.01754666	0.46322662	0.02202241	0.08147008
DBH	10	22.84283236	5.10028891	228.42832364	15.39219436	31.77531676
HI	10	11.82904621	1.65385749	118.29046210	9.06171860	13.73489696
HBLC	10	4.37299905	1.20919359	43.72999048	2.07016002	6.33267710
CL	10	7.45604716	1.41828153	74.56047162	5.12799440	9.55012213
CR	10	62.78870792	9.07018916	627.88707924	48.95845681	78.58392348
DABA	10	24.30455479	4.72384218	243.04554793	17.04053563	32.77554324
ASPECT	10	183.80000000	82.89189747	1838.00000000	55.00000000	311.00000000
GASPECT	10	3.00000000	0.66666667	30.00000000	2.00000000	4.00000000
COSA	10	-0.35126596	0.74794025	-3.51265958	-0.99756491	0.65604326
COSA-S	10	-0.09626596	0.69930160	-0.96265958	-0.73452320	0.85462197
SINA	10	-0.00495512	0.64387242	-0.04955119	-0.83868165	0.96592452
SINA-S	10	-0.25995512	0.68805703	-2.59955119	-1.14868165	0.85592452
CCOV	10	61.52500000	10.04396585	615.25000000	51.00000000	80.00000000

[a]See Table 1 for definitions.

TABLE 26.--Summary statistics for the PSME/SYAL/CAGE community type -- Gallatin

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	8	20.15363065	27.06268754	161.22904522	0	62.85870404
ELEV	8	2078.12830000	127.25276456	6625.02640000	1913.00000000	2320.00000000
SLOPE	8	35.37500000	11.57506557	283.00000000	21.00000000	57.00000000
STH	8	1090.34563660	569.39469369	8722.76509283	432.79062526	1969.29085584
SBA	8	59.47043061	14.94088701	475.76344489	32.13955003	82.64455723
SDIA	8	25580.69063240	8171.06234596	24645.52505916	17372.87182753	38994.69874086
ADA	8	0.07183983	0.04876571	0.57471860	0.02942648	0.16973988
DBH	8	27.04089137	9.55775341	216.32713099	16.90862429	43.79957683
HI	8	17.51042184	3.36259216	140.08337473	14.12311631	23.24298406
HBLC	8	7.82465595	2.25363495	62.59724762	4.91226389	10.89956585
CL	8	9.68576589	2.00736103	77.48612711	7.01503912	13.02141128
CR	8	56.65362876	10.33779448	453.22903010	39.51021170	73.80099460
DABA	8	29.44719814	9.56885446	235.57758508	19.69790244	47.30889266
ASPECT	8	211.00000000	101.42977866	1688.00000000	100.00000000	330.00000000
GASPECT	8	2.75000000	1.16496475	22.00000000	1.00000000	4.00000000
COSA	8	0.04748775	0.59136444	0.37990200	-0.99619578	0.86601432
COSA-S	8	0.40123775	0.58765550	3.20990200	-0.61619578	1.29601432
SINA	8	-0.03584680	0.88831269	-0.28677439	-0.99619315	0.98480892
SINA-S	8	-0.38959680	0.87464507	-3.11677439	-1.36619315	0.77480892
CCOV	8	60.03125000	5.31244748	480.25000000	55.00000000	70.00000000

[a]See Table 1 for definitions.

TABLE 27.--Summary statistics for the PSME/SYAL/FEID community type -- Gallatin

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	8	56.31053997	23.55993560	450.48431975	14.61945468	88.43887329
ELEV	8	2040.37500000	73.87428994	6323.00000000	1953.00000000	2132.00000000
SLOPE	8	36.00000000	14.40238076	288.00000000	13.00000000	57.00000000
STII	8	1134.52525012	820.39264302	9076.20200094	399.61488782	2739.74919073
SBA	8	43.50357648	14.58453395	348.02861182	27.54818574	73.46182865
SDIA	8	21873.53699196	8794.20577045	14988.29593569	11320.27163222	36039.92746173
ABA	3	0.05210267	0.02469634	0.41682138	0.01307267	0.09146375
DBH	8	23.36575834	6.89823486	186.92606675	9.83197102	32.32594296
HI	8	14.94388450	3.76850145	119.55107597	6.09361534	18.12788761
HBLC	8	7.77926432	2.57681244	62.23411455	3.05986173	10.80833331
CL	8	7.16462018	2.53996468	57.31696141	3.03375361	11.72612921
CR	8	47.28281043	10.70326687	378.26248342	38.14198133	71.95395266
DABA	8	25.42427668	6.81292588	203.39421344	13.12904102	34.72764636
ASPECT	8	148.75000000	138.89230155	1190.00000000	10.00000000	355.00000000
GASPECT	8	2.00000000	1.30930734	16.00000000	1.00000000	4.00000000
COSA	8	0.55232334	0.40719588	4.41858673	-0.17364156	0.99619262
COSA-S	8	0.91232334	0.37083685	7.29858673	0.14635844	1.24619262
SINA	8	0.16849118	0.77198610	1.34792945	-0.93969928	0.98480892
SINA-S	8	-0.19150882	0.78805713	-1.53207055	-1.50969928	0.66480892
CCOV	8	50.62500000	4.95515604	405.00000000	45.00000000	60.00000000

[a]See Table 1 for definitions.

TABLE 28.--Summary statistics for the PSME/SYAL/CARU community type -- Gallatin

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	6	73.44803500	22.12553298	440.68820999	34.87647451	100.00000000
ELEV	6	2056.83800000	60.51260252	2341.02800000	1987.00000000	2129.02800000
SLOPE	6	26.66666667	14.12326686	160.00000000	7.00000000	46.00000000
STH	6	1137.81083449	525.00089734	6826.86500692	370.05948310	1906.91718113
SBA	6	46.79806486	27.90486292	280.78838916	27.54818574	98.87225886
SDIA	6	22715.51159148	11310.41730928	16293.06954888	10347.34157793	43426.94677221
ABA	6	0.04334849	0.01729210	0.26009092	0.02909889	0.07444259
DBH	6	20.68107845	4.18965217	124.08647069	16.73416551	27.96129285
HI	6	12.02142049	1.09653679	72.12852296	10.02001467	13.06276853
HBLC	6	3.54382143	0.68679796	21.26292855	2.91780326	4.70176520
CL	6	8.47759907	1.40673276	50.86559441	6.42854728	10.00435733
CR	6	67.34823019	9.85576950	404.08938115	51.95106871	76.09827994
DABA	6	23.55620673	4.47436342	141.33724038	19.58795148	31.33008479
ASPECT	6	206.50000000	57.37159576	1239.00000000	125.00000000	265.00000000
GASPECT	6	3.50000000	0.83666003	21.00000000	2.00000000	4.00000000
COSA	6	-0.53102619	0.24139492	-3.18615711	-0.80901131	-0.08717347
COSA-S	6	-0.26435952	0.28388730	-1.58615711	-0.57279944	0.26282653
SINA	6	-0.34007301	0.81520693	-2.04043806	-0.99619315	0.81915686
SINA-S	6	-0.60673968	0.73728855	-3.64043806	-1.34619315	0.48915686
CCOV	6	54.33333333	6.68331255	326.00000000	45.00000000	65.00000000

[a]See Table 1 for definitions.

TABLE 29.--Summary statistics for the PSME/CARU/CARU community type -- Gallatin

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	9	50.24937705	22.33963007	452.24439347	15.43304701	77.11297004
ELEV	9	2057.88888889	51.94334521	8521.00000000	1961.00000000	2133.00000000
SLOPE	9	41.33333333	8.63133825	372.00000000	30.00000000	57.00000000
STH	9	1327.95793160	707.56165221	1951.62138444	536.57436349	2438.88301222
SBA	9	52.88384512	16.89961117	475.95460608	20.81906593	73.46182865
SDIA	9	25337.21368977	7291.86180338	28034.92320794	13192.97588137	34940.25203836
ABA	9	0.05115153	0.03035946	0.46036380	0.01506055	0.10268171
DBH	9	22.17600276	8.13777137	199.58402480	11.11288655	33.74008843
HI	9	14.90371119	5.04708699	134.13340068	6.76304656	21.56932501
HBLC	9	6.85920790	2.27492993	61.73287112	3.32557652	10.16831301
CL	9	8.04450328	3.23892129	72.40052956	3.43747004	12.45928692
CR	9	52.98893170	7.40035469	476.90038534	40.38915452	64.90595828
DABA	9	24.87505653	7.91582142	223.87550877	14.09195420	36.79572610
ASPECT	9	189.44444444	137.37367935	1705.00000000	40.00000000	320.00000000
GASPECT	9	2.44444444	1.50923086	22.00000000	1.00000000	4.00000000
COSA	9	0.62531890	0.15294953	5.62787011	0.34200184	0.76604617
COSA-S	9	1.03865223	0.18415917	9.34787011	0.70200184	1.24603063
SINA	9	-0.13443004	0.80085853	-1.20987038	-0.93969928	0.81914993
SINA-S	9	-0.54776338	0.81298909	-4.92987038	-1.43603548	0.49914993
CCOV	9	49.44444444	9.16666667	445.00000000	40.00000000	65.00000000

[a]See Table 1 for definitions.

TABLE 30.--Summary statistics for the PSME/LIBO community type -- Gallatin

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	7	33.37743935	19.10308999	233.64207548	13.18684411	62.18168958
ELEV	7	2073.87702857	45.77864699	4517.13920000	2028.13920000	2157.00000000
SLOPE	7	37.71428571	10.07826516	264.00000000	19.00000000	50.00000000
STH	7	1095.17275399	742.49492487	7666.20927795	319.20030998	2214.68914546
SBA	7	54.91574123	16.19129099	384.41018864	27.54818574	73.46182865
SDIA	7	24962.83045444	9988.56466104	14739.81318107	10438.90769537	38262.24921126
ABA	7	0.07229216	0.04858295	0.50604511	0.02223364	0.16831419
DBH	7	27.84402936	9.58675276	194.90820552	13.95265614	43.40537085
HI	7	20.17700707	7.11766113	141.23904951	10.02180576	27.51647085
HBLC	7	11.30403731	4.80840450	79.12826119	4.94359069	18.82847622
CL	7	8.87296976	3.87641087	62.11078832	4.29968343	15.17392231
CR	7	44.16365189	12.30168242	309.14556321	30.54918629	62.48804748
DABA	7	29.49440728	9.85812063	206.46085099	17.12206326	47.10979566
ASPECT	7	150.71428571	149.20423842	1055.00000000	20.00000000	350.00000000
GASPECT	7	1.85714286	1.46385011	13.00000000	1.00000000	4.00000000
COSA	7	0.70002719	0.29987721	4.90019030	0.17362966	0.98480367
COSA-S	7	1.07717004	0.37722924	7.54019030	0.36362966	1.44480367
SINA	7	0.00710390	0.71061268	0.04972731	-0.98481102	0.70710464
SINA-S	7	-0.37003896	0.68128619	-2.59027269	-1.32631616	0.35710464
CCOV	7	58.25000000	6.23999199	407.75000000	50.00000000	70.00000000

[a]See Table 1 for definitions.

TABLE 31.--Summary statistics for the Yellowstone study area

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	72	66.27165248	19.72021210	4771.5589788	0	100.00000000
ELEV	70	2013.58577143	71.17340574	40951.0040000	1880.00000000	2175.05280000
SLOPE	72	42.25000000	21.40142815	3042.0000000	0	92.00000000
STH	72	1737.91431010	1166.16507419	25129.8303273	130.42617647	5190.84198795
SBA	72	45.25545951	14.56015300	3258.3930850	18.36545716	73.46182865
SDIA	72	27604.93986479	11240.02587064	187555.6702652	6037.07443536	53021.15386665
ABA	72	0.04300412	0.04137476	3.0962966	0.00447219	0.23354558
DBH	72	20.25864983	9.13420659	1458.6227879	6.77303449	54.23976441
HI	72	13.37153459	3.87539546	962.7504905	5.45617944	23.49327369
HBLC	72	7.04550843	2.57679432	507.2766072	2.12035536	14.29816872
CL	72	6.32602616	3.18921462	455.4738833	1.93539631	17.18627120
CR	72	45.76757966	15.02659794	3295.2657359	20.04508100	81.89495978
DABA	72	22.04100999	9.07609087	1586.9527193	7.67911461	55.49280285
ASPECT	72	122.34722222	122.69923835	8809.0000000	0	358.00000000
GASPECT	72	1.63888889	0.89293874	118.0000000	1.00000000	4.00000000
COSA	72	0.49265008	0.60946711	35.4708058	-0.90630339	1.00000000
COSA-S	72	0.91515008	0.66786422	65.8908058	-0.72804283	1.91619262
SINA	72	0.32621290	0.53721339	23.4873287	-0.88293996	1.00000000
SINA-S	72	-0.09628710	0.57046802	-6.9326713	-1.39601734	0.80718667
CCOV	71	60.20422535	8.12396256	4274.5000000	45.00000000	80.00000000

[a]See Table 1 for definitions.

TABLE 32.--Correlation matrix of site, stand, and defoliation variables[a] on the Yellowstone study area

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	PDI	ELEV	SLOPE	STH	SBA	SDIA	ABA	DBH	HI	HBLC	CL	CR	DABA
PDI	1.00000	-0.09593	0.14781	0.24386	0.08743	0.26333	-0.38370	-0.41086	-0.40114	-0.11378	-0.39552	-0.19119	-0.39976
	0.0000	0.4295	0.2153	0.0390	0.4652	0.0254	0.0009	0.0003	0.0005	0.3413	0.0006	0.1077	0.0005
	72	70	72	72	72	72	72	72	72	72	72	72	72
ELEV	-0.09593	1.00000	-0.08865	-0.04286	0.15855	0.01396	0.15571	0.13177	0.00058	-0.28911	0.23151	0.33336	0.14885
	0.4295	0.0000	0.4655	0.7246	0.1899	0.9087	0.1980	0.2769	0.9962	0.0152	0.0538	0.0048	0.2188
	70	70	70	70	70	70	70	70	70	70	70	70	70
SLOPE	0.14781	-0.08865	1.00000	0.30349	-0.19822	0.14643	-0.37138	-0.43015	-0.29544	-0.00975	-0.35113	-0.31504	-0.42070
	0.2153	0.4655	0.0000	0.0096	0.0951	0.2197	0.0013	0.0002	0.0118	0.9352	0.0025	0.0070	0.0002
	72	70	72	72	72	72	72	72	72	72	72	72	72
ASPECT	-0.26080	-0.16251	0.08029	0.11447	-0.03599	0.09026	-0.10599	-0.08946	-0.07917	0.01906	-0.11160	-0.09095	-0.11226
	0.0269	0.1789	0.5026	0.3384	0.7641	0.4509	0.3755	0.4549	0.5086	0.8738	0.3506	0.4474	0.3478
	72	70	72	72	72	72	72	72	72	72	72	72	72
GASPECT	0.02287	0.30477	0.02174	0.04808	0.12741	0.05810	-0.00982	-0.02941	-0.23873	-0.52172	0.13144	0.44876	-0.01879
	0.8488	0.0103	0.8561	0.6884	0.2862	0.6278	0.9348	0.8063	0.0434	0.0001	0.2711	0.0001	0.8755
	72	70	72	72	72	72	72	72	72	72	72	72	72
COSA	-0.08347	-0.37136	0.11036	0.11310	-0.12922	0.02330	-0.08084	-0.08941	0.15573	0.53010	-0.23907	-0.56147	-0.09141
	0.4857	0.0016	0.3561	0.3442	0.2793	0.8460	0.4997	0.4551	0.1915	0.0001	0.0431	0.0001	0.4451
	72	70	72	72	72	72	72	72	72	72	72	72	72
COSA-S	-0.02881	-0.36780	0.42116	0.20047	-0.18144	0.06819	-0.19277	-0.21943	0.04744	0.48063	-0.33069	-0.61333	-0.21823
	0.8102	0.0017	0.0002	0.0913	0.1272	0.5693	0.1047	0.0640	0.6923	0.0001	0.0046	0.0001	0.0655
	72	70	72	72	72	72	72	72	72	72	72	72	72
SINA	0.19541	0.26294	0.03899	0.03111	-0.11252	-0.00633	-0.05980	-0.09332	-0.08050	-0.14596	0.02011	0.08973	-0.08288
	0.1000	0.0279	0.7450	0.7953	0.3467	0.9579	0.6178	0.4356	0.5014	0.2212	0.8669	0.4535	0.4888
	72	70	72	72	72	72	72	72	72	72	72	72	72
SINA-S	0.12857	0.28088	-0.33843	-0.08456	-0.03160	-0.06089	0.08301	0.07349	0.03502	-0.13380	0.15066	0.20269	0.07978
	0.2818	0.0185	0.0036	0.4801	0.7922	0.6114	0.4881	0.5395	0.7702	0.2625	0.2065	0.0877	0.5053
	72	70	72	72	72	72	72	72	72	72	72	72	72
CCOV	-0.00730	0.14530	0.10958	0.32797	0.31514	0.34485	-0.04368	-0.08500	-0.01866	-0.05246	0.01994	-0.04601	-0.07510
	0.9518	0.2336	0.3630	0.0052	0.0074	0.0032	0.7176	0.4809	0.8772	0.6639	0.8689	0.7032	0.5336
	71	69	71	71	71	71	71	71	71	71	71	71	71

[a]See Table 1 for definitions.

TABLE 33 .--Summary statistics for the PSME/FEID/CAGE community type -- Yellowstone

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	8	73.76443008	13.30312329	590.11544060	51.39840782	95.72974010
ELEV	8	2015.58650000	66.18535823	6124.69200000	1912.00000000	2128.11360000
SLOPE	8	26.37500000	16.39631927	211.00000000	11.00000000	59.00000000
STH	8	1652.41144378	855.01537615	3219.29155025	319.33077062	3010.86783879
SBA	8	44.06603362	15.73542156	352.52826893	18.36545716	64.27910007
SDIA	8	27757.19459236	11571.28853256	22057.55673888	11876.65483518	39940.78204913
ABA	8	0.03671698	0.03235737	0.29373582	0.01537081	0.11502466
DBH	8	19.18411386	7.65854164	153.47291087	13.26553811	37.19232823
HI	8	11.61101917	3.11180826	92.88815335	8.87988071	18.82940264
HBLC	8	5.58074707	2.18140602	44.64597657	2.12035536	8.39576469
CL	8	6.03027210	2.06402288	48.24217678	4.27257369	10.43363796
CR	8	52.03821690	14.06871706	416.30573518	36.90071587	75.82888496
DABA	8	20.77351470	7.75322598	166.18811760	14.23636759	38.94451708
ASPECT	8	84.37500000	42.17290091	675.00000000	35.00000000	145.00000000
GASPECT	8	2.00000000	0.53452248	16.00000000	1.00000000	3.00000000
COSA	8	0.09295769	0.65634191	0.74366155	-0.81914646	0.81915339
COSA-S	8	0.35670769	0.65010696	2.85366155	-0.63914646	0.92915339
SINA	8	0.77139245	0.14880837	6.17113960	0.57357451	0.96592452
SINA-S	8	0.50764245	0.11705914	4.06113960	0.37592452	0.71969101
CCOV	8	51.43750000	8.15119404	411.50000000	45.00000000	70.00000000

[a]See Table 1 for definitions.

TABLE 34.--Summary statistics for the PSME/SYAL/CAGE community type -- Yellowstone

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	13	69.46028794	16.22798380	902.98374326	43.85697031	100.00000000
ELEV	13	2040.71950769	76.99022341	6529.35360000	1950.11040000	2175.05280000
SLOPE	13	33.38461538	20.03554534	434.00000000	5.00000000	63.00000000
STH	13	1395.46725497	1036.29671682	8141.07431462	433.17952560	4542.45070650
SBA	13	52.33552111	15.87062305	680.36177449	27.54818574	73.46182865
SDIA	13	26463.97974288	9012.15753129	34031.73665742	11423.07579281	38427.26091160
ABA	13	0.04741866	0.01848262	0.61644258	0.00800005	0.08274249
DBH	13	22.07352497	5.81122507	286.95582466	8.06746792	30.83862715
HI	13	13.74387194	2.89341500	178.67033522	6.98278099	17.75577147
HBLC	13	6.58089247	2.26080743	85.55160212	2.32178179	10.31406410
CL	13	7.16297947	2.20607955	93.11873310	2.35529967	10.69921140
CR	13	51.40236175	13.89168967	668.23070273	31.43247815	80.53710442
DABA	13	24.43577902	5.52119960	317.66512723	10.27063439	33.03049941
ASPECT	13	158.00000000	126.90087995	2054.00000000	5.00000000	350.00000000
GASPECT	13	2.15384615	1.34450448	28.00000000	1.00000000	4.00000000
COSA	13	0.24082666	0.83073167	3.13074660	-0.87462651	0.99619473
COSA-S	13	0.57467282	0.85209522	7.47074660	-0.72804283	1.62619473
SINA	13	-0.03570344	0.57359102	-0.46414474	-0.77713620	0.64279481
SINA-S	13	-0.36954960	0.61015702	-4.80414474	-1.32712174	0.40992769
CCOV	12	61.16666667	7.04477025	734.00000000	45.00000000	70.00000000

[a]See Table 1 for definitions.

TABLE 35.--Summary statistics for the PSME/SYAL/FEID community type -- Yellowstone

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	9	68.51699146	15.76516127	616.65292314	44.08736929	96.11891841
ELEV	8	2023.12180000	93.70576386	6184.97440000	1921.00000000	2161.03200000
SLOPE	9	40.44444444	18.18729715	364.00000000	12.00000000	68.00000000
STH	9	1659.04571328	1110.81856811	4931.41141953	157.27514458	3269.95545169
SBA	9	41.00895216	15.33236648	369.08056942	22.95682145	64.27910007
SDIA	9	26217.00484357	13155.69067006	25953.04359216	8530.56678922	46576.09878849
ABA	9	0.05165700	0.06962946	0.46491300	0.00930368	0.23354558
DBH	9	21.75616299	13.25758470	195.80546695	9.05017258	54.23976441
HI	9	12.78356537	5.12226845	115.05208832	5.81064372	22.28850569
HBLC	9	6.27570425	2.79480609	56.48133828	2.42586315	10.78987940
CL	9	6.50786111	4.32647733	58.57075003	3.38478058	17.18627120
CR	9	48.12725901	14.45780512	433.14533105	30.39924921	76.25826082
DABA	9	22.97049709	13.14053043	206.73447383	11.07587886	55.49280285
ASPECT	9	132.66666667	124.38046470	1194.00000000	20.00000000	355.00000000
GASPECT	9	1.55555556	0.72648316	14.00000000	1.00000000	3.00000000
COSA	9	0.37295980	0.70076215	3.35663823	-0.90630339	0.99619262
COSA-S	9	0.77740425	0.78852659	6.99663823	-0.54630339	1.67619262
SINA	9	0.43339543	0.51588319	3.90055889	-0.64280407	0.95630686
SINA-S	9	0.02895099	0.64100829	0.26055889	-1.20280407	0.80718667
CCOV	9	59.88888889	6.15948343	539.00000000	50.00000000	70.00000000

[a]See Table 1 for definitions.

TABLE 36.--Summary statistics for the PSME/CARU/CARU community type -- Yellowstone

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	21	58.50088880	21.34820285	1228.51866490	20.88443390	99.60743872
ELEV	21	1997.89855238	59.70146022	1955.86960000	1892.00000000	2129.00000000
SLOPE	21	42.76190476	22.75061485	898.00000000	0	92.00000000
STH	21	1540.65940896	1081.37350060	2353.84758825	173.29140869	4830.42155870
SBA	21	45.81815163	13.96988502	962.18118433	27.54818574	68.00536681
SDIA	21	25939.21538348	11913.34909552	54723.52305314	8368.28025062	53021.15386665
ABA	21	0.04871626	0.04498359	1.02304140	0.01068975	0.18546534
DBH	21	21.43024608	10.00642536	450.03516764	9.01576244	48.29022001
HI	21	15.20982110	3.90802165	319.40624318	6.04920565	23.49327369
HBLC	21	8.41417887	2.88439565	176.69775623	3.05891651	14.29816872
CL	21	6.79564224	3.73481501	142.70848695	2.99028914	15.29964953
CR	21	42.36133949	16.72648169	889.58812926	24.64698513	81.89495978
DABA	21	23.55594207	9.58368235	494.67478346	11.87229114	49.45181295
ASPECT	21	120.66666667	148.38070405	2534.00000000	5.00000000	358.00000000
GASPECT	21	1.14285714	0.35856858	24.00000000	1.00000000	2.00000000
COSA	21	0.86228035	0.18261004	18.10788727	0.34202456	0.99938999
COSA-S	21	1.28989939	0.28065260	27.08788727	0.65947524	1.91619262
SINA	21	0.27306915	0.39705757	5.73445210	-0.42263865	0.93969101
SINA-S	21	-0.15454990	0.44778310	-3.24554790	-1.00717950	0.69294564
CCOV	21	62.72619048	9.14942101	1317.25000000	45.00000000	80.00000000

[a]See Table 1 for definitions.

TABLE 37.--Summary statistics for the PSME/LIBO community type -- Yellowstone

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	4	56.14177734	26.41965200	224.56710935	25.02964856	89.51907479
ELEV	4	1988.00000000	17.49285568	7952.00000000	1962.00000000	2000.00000000
SLOPE	4	35.25000000	20.61350690	141.00000000	15.00000000	62.00000000
STH	4	1371.32774151	1307.34233589	5485.31096606	130.42617647	3136.78483113
SBA	4	41.09557160	22.30780796	164.38228642	22.95682145	73.46182865
SDIA	4	22768.96524247	13975.79389618	1075.86096987	6037.07443536	35843.14839358
ABA	4	0.07169891	0.07212921	0.28679565	0.00995692	0.17601391
DBH	4	25.99281761	14.90147256	103.97127043	10.39598037	46.28729139
HI	4	15.49843639	4.83680484	61.99374557	10.23255121	21.58021879
HBLC	4	7.57222347	1.45254551	30.28889390	5.48874838	8.86590578
CL	4	7.92621292	4.60008290	31.70485167	2.30603087	13.57249939
CR	4	48.57771013	18.77676054	194.31084051	21.85918706	61.78972654
DABA	4	27.79692037	15.17578236	111.18768149	11.45812065	48.17528967
ASPECT	4	106.25000000	162.65377340	425.00000000	20.00000000	350.00000000
GASPECT	4	1.00000000	0	4.00000000	1.00000000	1.00000000
COSA	4	0.92083581	0.07104551	3.68334322	0.81915339	0.98480367
COSA-S	4	1.27333581	0.26806102	5.09334322	0.96915339	1.60480367
SINA	4	0.27098524	0.31589623	1.08394094	-0.17367133	0.57357451
SINA-S	4	-0.08151476	0.51527358	-0.32605906	-0.79367133	0.42357451
CCOV	4	61.25000000	4.78713554	245.00000000	55.00000000	65.00000000

[a]See Table 1 for definitions.

TABLE 38.--Summary statistics for the PSME/PHMA community type -- Yellowstone

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	14	73.21479592	10.11491064	1025.00714288	46.59832946	84.19143296
ELEV	14	2013.85714286	85.37325932	8194.00000000	1880.00000000	2162.00000000
SLOPE	14	61.00000000	15.23659562	854.00000000	25.00000000	76.00000000
STH	14	2586.56805409	1400.52938780	6211.95275719	754.94736423	5190.84198795
SBA	14	42.24306466	12.32966387	591.40290527	22.95682145	64.27910007
SDIA	14	33492.20097762	10582.81476472	48890.81368667	15102.26217435	51116.95032051
ABA	14	0.02105253	0.01139761	0.29473537	0.00447219	0.04865361
DBH	14	14.93947020	4.55228798	209.15258273	6.77303449	24.39560382
HI	14	11.24960264	3.06432504	157.49443702	5.45617944	15.60298488
HBLC	14	6.77220551	2.15935425	94.81087717	3.52078313	11.12089915
CL	14	4.47739713	1.65530057	62.68355985	1.93539631	7.52389553
CR	14	39.00201961	9.76918545	546.02827455	20.04508100	56.74941104
DABA	14	16.09366811	4.47379067	225.31135352	7.67911461	25.32843585
ASPECT	14	101.78571429	105.64103120	1425.00000000	0	355.00000000
GASPECT	14	1.64285714	0.49724516	23.00000000	1.00000000	2.00000000
COSA	14	0.46273826	0.43924108	6.47833570	-0.42261126	1.00000000
COSA-S	14	1.07273826	0.48321853	15.01833570	0.07738874	1.64619262
SINA	14	0.60488003	0.50928177	8.46832036	-0.57359432	1.00000000
SINA-S	14	-0.00511997	0.50258623	-0.07167964	-1.10359432	0.75000000
CCOV	14	62.50000000	5.80119351	875.00000000	50.00000000	70.00000000

[a]See Table 1 for definitions.

TABLE 39.--Summary statistics for the Bear Creek study area

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	27	42.93045797	19.82894154	1159.12236510	12.50000000	79.94598412
ELEV	27	2032.40740741	102.12558606	4875.00000000	1876.00000000	2183.00000000
SLOPE	27	46.00000000	15.71868070	1242.00000000	8.00000000	71.00000000
STH	27	2147.60016297	2019.32809760	7985.20440032	442.59565906	9805.91905540
SBA	27	47.82536485	26.31302413	1291.28485083	27.54818574	153.56781792
SDIA	27	31787.50122582	18478.40419620	88262.53309705	12308.98080728	77484.32111150
ABA	27	0.03101664	0.01451519	0.83744930	0.00662381	0.06224233
DBH	27	18.19111227	4.97135113	491.16003118	7.90179081	27.81089366
HI	27	11.39859478	2.23654461	307.76205916	6.52264313	16.05732435
HBLC	27	6.94293935	1.94751985	187.45936251	3.62609449	10.95993756
CL	27	4.45565543	1.65521999	120.30269665	1.62181935	7.93343866
CR	27	37.77846770	11.89654073	1020.01862781	22.57700797	63.28776799
DABA	27	19.64617616	4.88744978	530.44675623	9.34554742	28.64796412
ASPECT	27	260.92592593	99.53774929	7045.00000000	20.00000000	345.00000000
GASPECT	27	2.62962963	1.47147619	71.00000000	1.00000000	4.00000000
COSA	27	0.46178951	0.48760577	12.46831686	-0.57358937	0.96591983
COSA-S	27	0.92178951	0.48585912	24.88831686	-0.02203592	1.64968481
SINA	27	-0.51901303	0.54728019	-14.01335193	-1.00000000	0.86602339
SINA-S	27	-0.97901303	0.54668633	-26.43335193	-1.63619315	0.30604228
CCOV	27	57.40740741	7.64228751	1550.00000000	45.00000000	70.00000000

[a]See Table 1 for definitions.

TABLE 40--Correlation matrix of site, stand, and defoliation variables[a] on the Bear Creek study area

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 27

	PDI	ELEV	SLOPE	STH	SBA	SDIA	ABA	DBH	HI	HBLC	CL	CR	DABA
PDI	1.00000	0.02738	-0.05435	0.33453	0.05309	0.29739	-0.51712	-0.46018	0.06130	0.46425	-0.46340	-0.60563	-0.52253
	0.0000	0.8922	0.7877	0.0881	0.7925	0.1319	0.0057	0.0157	0.7613	0.0147	0.0149	0.0008	0.0052
ELEV	0.02738	1.00000	0.21290	0.33210	0.42161	0.38987	-0.14208	-0.24182	-0.19398	-0.22526	0.00293	0.06025	-0.14076
	0.8922	0.0000	0.2863	0.0906	0.0285	0.0444	0.4796	0.2243	0.3323	0.2586	0.9884	0.7653	0.4837
SLOPE	-0.05435	0.21290	1.00000	0.36211	0.39054	0.39478	-0.27265	-0.36517	-0.52497	-0.41198	-0.22461	0.01206	-0.26656
	0.7877	0.2863	0.0000	0.0634	0.0440	0.0416	0.1689	0.0611	0.0049	0.0327	0.2600	0.9524	0.1789
ASPECT	0.26191	-0.17806	-0.21079	0.05269	-0.26292	-0.07344	-0.00211	0.02502	-0.10810	0.00576	-0.15284	-0.09690	-0.03254
	0.1869	0.3742	0.2912	0.7941	0.1852	0.7158	0.9917	0.9014	0.5915	0.9772	0.4466	0.6307	0.8720
GASPECT	-0.63607	-0.08060	-0.14467	-0.46855	-0.25742	-0.49196	0.54780	0.49450	0.00405	-0.33108	0.39502	0.48956	0.54293
	0.0004	0.6894	0.4716	0.0137	0.1949	0.0092	0.0031	0.0087	0.9840	0.0916	0.0414	0.0095	0.0034
COSA	0.79129	0.06272	-0.17227	0.40372	0.15612	0.42171	-0.63039	-0.53724	0.10797	0.53083	-0.47868	-0.64737	-0.61329
	0.0001	0.7560	0.3902	0.0368	0.4368	0.0285	0.0004	0.0039	0.5919	0.0044	0.0115	0.0003	0.0007
COSA-S	0.77655	0.13183	0.15063	0.52232	0.28303	0.55094	-0.72087	-0.65732	-0.06148	0.39945	-0.55306	-0.64579	-0.70173
	0.0001	0.5122	0.4533	0.0052	0.1526	0.0029	0.0001	0.0002	0.7606	0.0390	0.0028	0.0003	0.0001
SINA	0.37788	0.06321	0.14738	0.26117	0.40657	0.38058	-0.36475	-0.35062	0.14871	0.24742	-0.09018	-0.23430	-0.33850
	0.0520	0.7541	0.4632	0.1882	0.0353	0.0502	0.0614	0.0730	0.4591	0.2134	0.6547	0.2395	0.0842
SINA-S	0.39392	0.00207	-0.13998	0.15734	0.29472	0.26749	-0.28675	-0.24601	0.29981	0.36614	-0.02569	-0.23803	-0.26222
	0.0420	0.9918	0.4862	0.4332	0.1356	0.1774	0.1470	0.2161	0.1287	0.0603	0.8988	0.2319	0.1864
CCOV	-0.25071	0.36583	0.02241	0.11987	-0.04884	0.08400	-0.22749	-0.19134	-0.17077	-0.02920	-0.19640	-0.09128	-0.22477
	0.2072	0.0606	0.9116	0.5515	0.8089	0.6770	0.2538	0.3390	0.3944	0.8851	0.3262	0.6507	0.2597

[a]See Table 1 for definitions.

TABLE 41.--Summary statistics for the PSME/PHMA/SYAL community type -- Bear Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	5	37.68915903	21.85109062	188.44579514	14.28620561	65.09190241
ELEV	5	1949.20000000	44.27979223	9746.00000000	1876.00000000	1989.00000000
SLOPE	5	49.00000000	11.18033989	245.00000000	34.00000000	62.00000000
STH	5	2292.43567017	1962.89877570	1462.17835086	956.67357649	5759.92002722
SBA	5	47.07305365	23.65474263	235.36526825	31.27445248	88.07578102
SDIA	5	34163.34682559	22751.70002677	10816.73412793	19278.38981820	74320.81525125
ABA	5	0.02458608	0.00778111	0.12293040	0.01529115	0.03359511
DBH	5	16.44473008	3.03304336	82.22365041	12.90309846	20.15148144
HI	5	10.53780540	0.85464102	52.68902698	9.51292621	11.73941015
HBLC	5	6.71296378	1.42278448	33.56481888	5.20760055	8.81939671
CL	5	3.82484162	1.00704656	19.12420811	2.56517005	4.70050358
CR	5	35.48176838	10.54071534	177.40884191	23.44587476	44.68202407
DABA	5	17.81280850	2.93415377	89.06404248	14.19942841	21.04693426
ASPECT	5	248.00000000	117.29236974	1240.00000000	50.00000000	345.00000000
GASPECT	5	2.40000000	1.51657509	12.00000000	1.00000000	4.00000000
COSA	5	0.41715910	0.56214987	2.08579548	-0.34203592	0.96591983
COSA-S	5	0.90715910	0.53317863	4.53579548	0.23796408	1.43913952
SINA	5	-0.40121607	0.71780392	-2.00608034	-1.00000000	0.76604228
SINA-S	5	-0.89121607	0.76117642	-4.45608034	-1.51968688	0.30604228
CCOV	5	56.00000000	8.21583836	280.00000000	50.00000000	70.00000000

[a]See Table 1 for definitions.

TABLE 42.--Summary statistics for the PSME/PHMA/PHMA community type -- Bear Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	6	57.88380074	16.23974334	347.30280444	40.14265496	79.94598412
ELEV	6	2022.66666667	124.60765092	2136.00000000	1904.00000000	2183.00000000
SLOPE	6	56.83333333	12.73446766	341.00000000	36.00000000	71.00000000
STH	6	3697.76309152	3444.47127800	2186.57854912	977.32458860	9805.91905540
SBA	6	59.96460726	47.74799466	359.78764359	27.54818574	153.56781792
SDIA	6	43502.45440354	27146.98833711	21014.72642125	18279.95188101	77484.32111150
ABA	6	0.02406883	0.01326959	0.14441299	0.00662381	0.03517746
DBH	6	15.53619666	5.48795441	93.21717998	7.90179081	20.33245494
HI	6	10.94714539	2.95361213	65.68287237	6.52264313	13.33450331
HBLC	6	7.07226572	2.26143345	42.43359431	4.65320580	9.99333844
CL	6	3.87487968	2.23688317	23.24927806	1.62181935	7.93343866
CR	6	32.55822330	13.01683014	195.34933978	22.78242560	58.08171307
DABA	6	17.03660013	5.70447586	102.21960077	9.34554742	21.53689433
ASPECT	6	278.33333333	109.20927922	1670.00000000	60.00000000	345.00000000
GASPECT	6	2.16666667	1.47196014	13.00000000	1.00000000	4.00000000
COSA	6	0.69553244	0.28054725	4.17319467	0.25880056	0.96591983
COSA-S	6	1.26386578	0.35086850	7.58319467	0.74880056	1.64968481
SINA	6	-0.32781124	0.64173400	-1.96686744	-0.96593078	0.86602339
SINA-S	6	-0.89614457	0.56895639	-5.37686744	-1.45593078	0.19602339
CCOV	6	53.33333333	6.05530071	320.00000000	50.00000000	65.00000000

[a]See Table 1 for definitions.

TABLE 43.--Summary statistics for the PSME/FEID/FEID community type -- Bear Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	4	24.38372596	11.45140469	97.53490386	12.50000000	38.93924636
ELEV	4	2059.75000000	107.17392407	8239.00000000	1939.00000000	2153.00000000
SLOPE	4	47.50000000	13.69914839	190.00000000	32.00000000	64.00000000
STH	4	960.98363221	496.31414642	3843.93452884	534.19477291	1485.76572366
SBA	4	38.00975696	12.32440945	152.03902785	27.54818574	55.62037775
SDIA	4	18869.27556267	5438.56895555	5477.10225066	13700.15948346	24401.60163454
ABA	4	0.04430423	0.01402393	0.17721692	0.02860888	0.06016448
DBH	4	21.75045410	5.54548724	87.00181642	16.42358633	27.57238770
HI	4	11.17541178	3.07869169	44.70164711	7.55669412	14.68202786
HBLC	4	5.34326931	1.75813464	21.37307724	3.62609449	7.64772074
CL	4	5.83214247	1.41268129	23.32856987	3.93059963	7.03430711
CR	4	50.37793158	5.70662377	201.51172631	43.44205126	55.68597292
DABA	4	23.93486648	3.88199520	95.73946593	19.42232851	28.16572384
ASPECT	4	266.25000000	20.15564437	1065.00000000	250.00000000	295.00000000
GASPECT	4	4.00000000	0	16.00000000	4.00000000	4.00000000
COSA	4	-0.06636117	0.34281163	-0.26544468	-0.34203592	0.42260030
COSA-S	4	0.40863883	0.42919664	1.63455532	-0.02203592	0.94260030
SINA	4	-0.95202939	0.03823376	-3.80811758	-0.99619315	-0.90631616
SINA-S	4	-1.42702939	0.15646445	-5.70811758	-1.63619315	-1.25968688
CCOV	4	55.00000000	9.12870929	220.00000000	45.00000000	65.00000000

[a]See Table 1 for definitions.

TABLE 44.--Summary statistics for the PSME/SYAL/CAGE community type -- Bear Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	8	41.86107589	19.91506670	334.88860710	14.86572187	66.08941528
ELEV	8	2033.75000000	106.23659579	6270.00000000	1876.00000000	2148.00000000
SLOPE	8	35.12500000	19.91723948	281.00000000	8.00000000	66.00000000
STH	8	1531.72901566	973.40359597	2253.83212528	442.59565906	2938.18652895
SBA	8	44.28230800	18.52123858	354.25846403	27.54818574	77.18809539
SDIA	8	27130.77126555	13059.21278535	27046.17012438	12308.98080728	44080.39450846
ABA	8	0.03730476	0.01679862	0.29843810	0.01475737	0.06224233
DBH	8	20.39696807	5.30643513	163.17574454	12.92708083	27.81089366
HI	8	12.23060305	2.36153747	97.84482438	8.78405685	16.05732435
HBLC	8	7.35561101	2.22515218	58.84488805	3.79637458	10.95993756
CL	8	4.87499204	1.71860125	38.99993634	2.73969132	7.38900337
CR	8	39.31750812	13.39947304	314.54006494	22.57700797	63.28776799
DABA	8	21.63045940	5.23841988	173.04367517	13.94939114	28.64796412
ASPECT	8	296.25000000	36.62064211	2370.00000000	235.00000000	345.00000000
GASPECT	8	3.25000000	1.38873015	26.00000000	1.00000000	4.00000000
COSA	8	0.37884661	0.53663247	3.03077285	-0.57358937	0.96591983
COSA-S	8	0.73009661	0.39784762	5.84077285	0.08641063	1.29601432
SINA	8	-0.74088938	0.25203302	-5.92711508	-0.98481102	-0.25884143
SINA-S	8	-1.09213938	0.38714641	-8.73711508	-1.58480472	-0.33884143
CCOV	8	60.62500000	8.21040281	485.00000000	50.00000000	70.00000000

[a]See Table 1 for definitions.

TABLE 45.--Summary statistics for the PSME/CARU community type -- Bear Creek

VARIABLE[a]	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
PDI	4	47.73756364	17.01158674	190.95025457	27.31233087	67.49755911
ELEV	4	2121.00000000	29.68725877	8484.00000000	2090.00000000	2152.00000000
SLOPE	4	46.25000000	4.78713554	185.00000000	41.00000000	52.00000000
STH	4	2059.67021155	480.96928822	8238.68084621	1572.90551897	2585.20405814
SBA	4	47.45861178	6.68183872	189.83444712	39.18452309	55.09637149
SDIA	4	33476.95004321	6727.13617528	13907.80017283	27265.84996818	40117.53443177
ABA	4	0.02361272	0.00415424	0.09445089	0.01920154	0.02919034
DBH	4	16.38540996	1.37075795	65.54163984	14.85755658	17.87430959
HI	4	11.71092208	1.28926949	46.84368832	10.66687281	13.55265653
HBLC	4	7.81074601	1.41873968	31.24298405	6.76778680	9.86747140
CL	4	3.90017607	0.64894006	15.60070427	3.38137232	4.84963836
CR	4	32.80216372	5.49898390	131.20865487	26.63208802	39.88954913
DABA	4	17.59499297	1.53423868	70.37997187	15.91178546	19.61870766
ASPECT	4	175.00000000	173.25318660	700.00000000	20.00000000	325.00000000
GASPECT	4	1.00000000	0	4.00000000	1.00000000	1.00000000
COSA	4	0.86099963	0.05692821	3.44399854	0.81913952	0.93969308
COSA-S	4	1.32349963	0.09721319	5.29399854	1.22913952	1.45969308
SINA	4	-0.07629287	0.57784474	-0.30517150	-0.57359432	0.49999826
SINA-S	4	-0.53879287	0.56320653	-2.15517150	-1.05359432	0.05999826
CCOV	4	61.25000000	4.78713554	245.00000000	55.00000000	65.00000000

[a]See Table 1 for definitions.

Appendix B

Figures 2 - 12

Figure 2. Average hourly ambient temperatures for December 13-17, 1979, at three sites on the Wall Creek elk winter range.

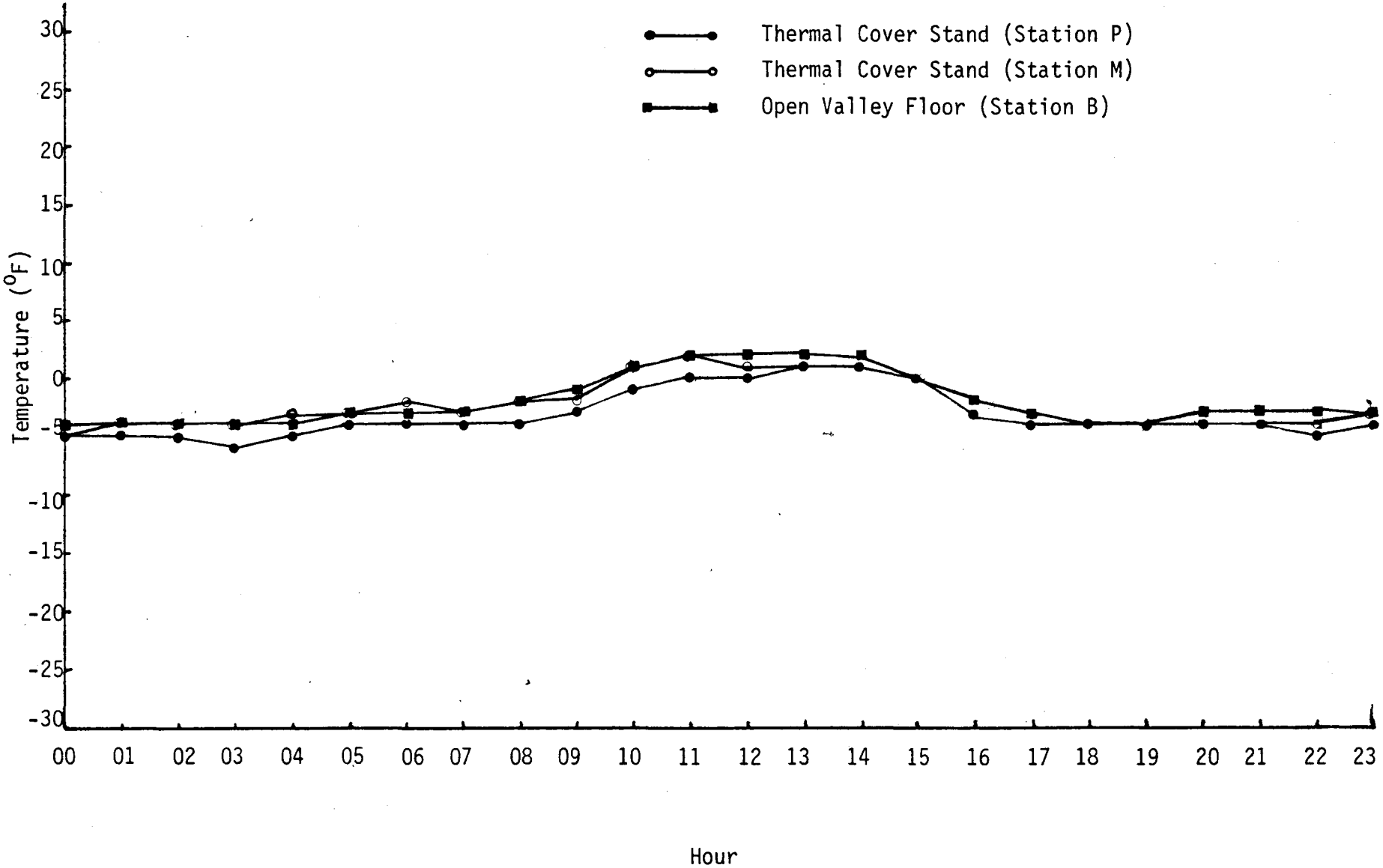


Figure 3. Average hourly wind flow/hour for December 13-17, 1979, at four sites on the Wall Creek elk winter range.

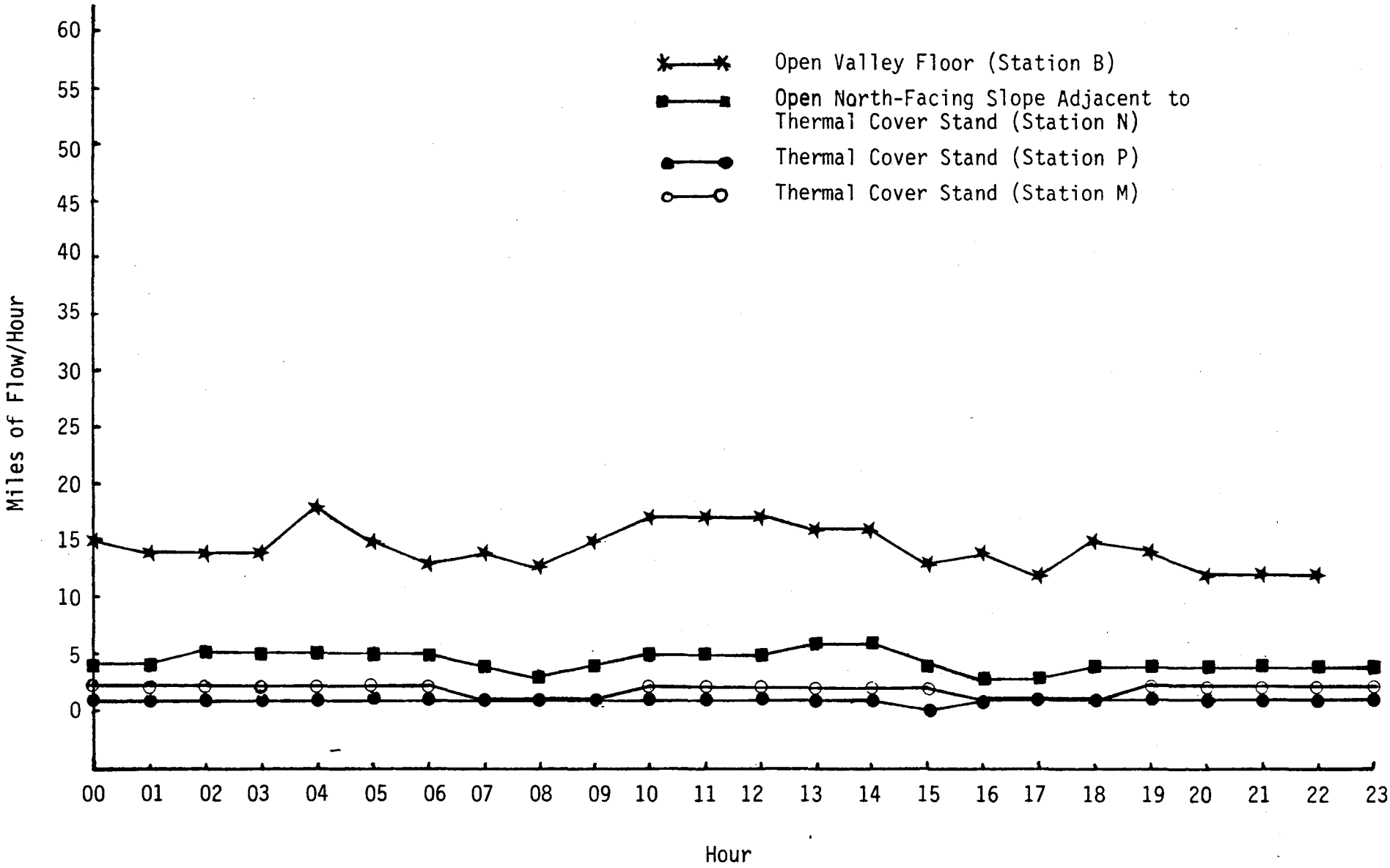


Figure 4. Average hourly ambient temperatures for January 12-16, 1980, at three sites on the Wall Creek elk winter range.

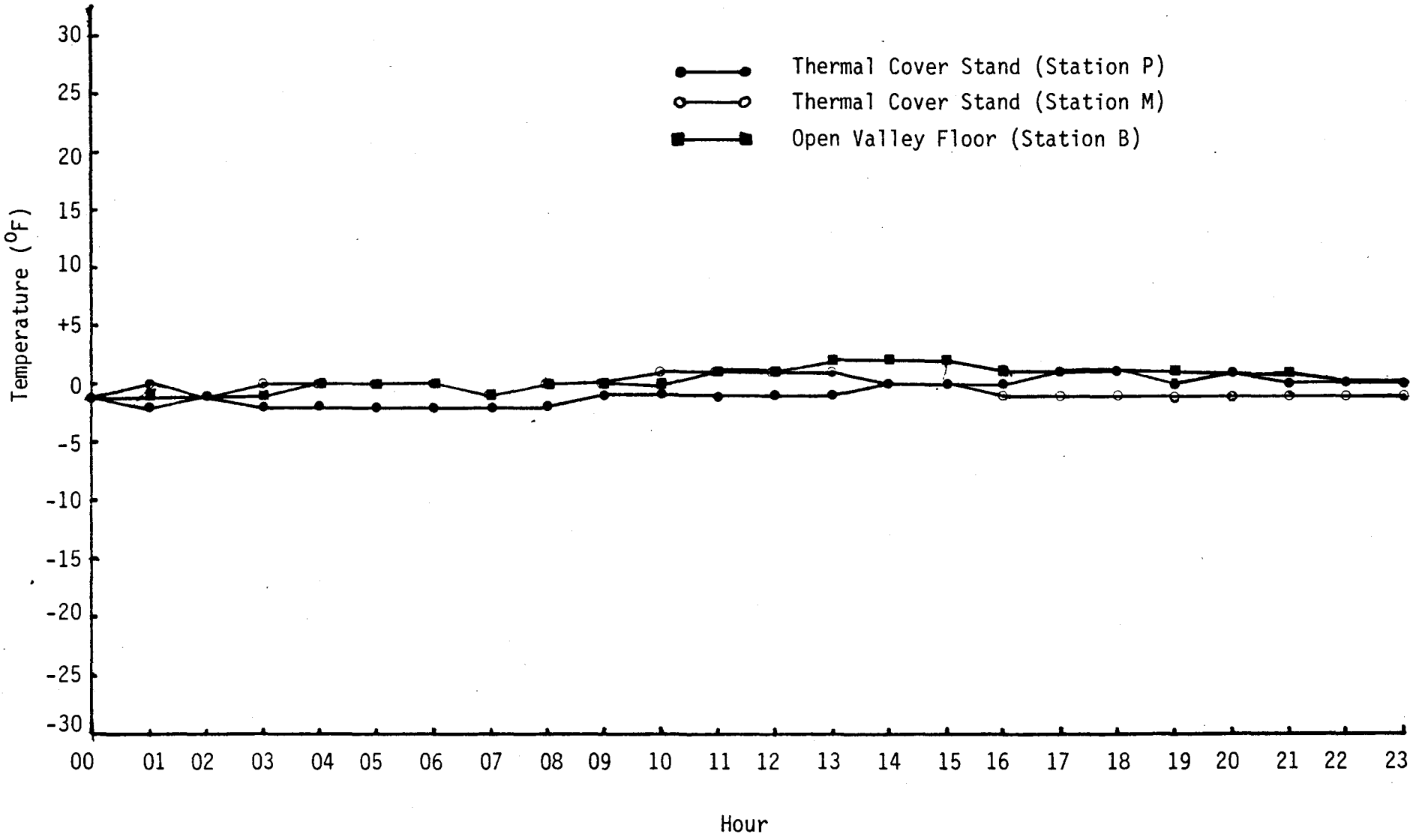


Figure 5. Average hourly wind flow/hour for January 12-16, 1980, at four sites on the Wall Creek elk winter range.

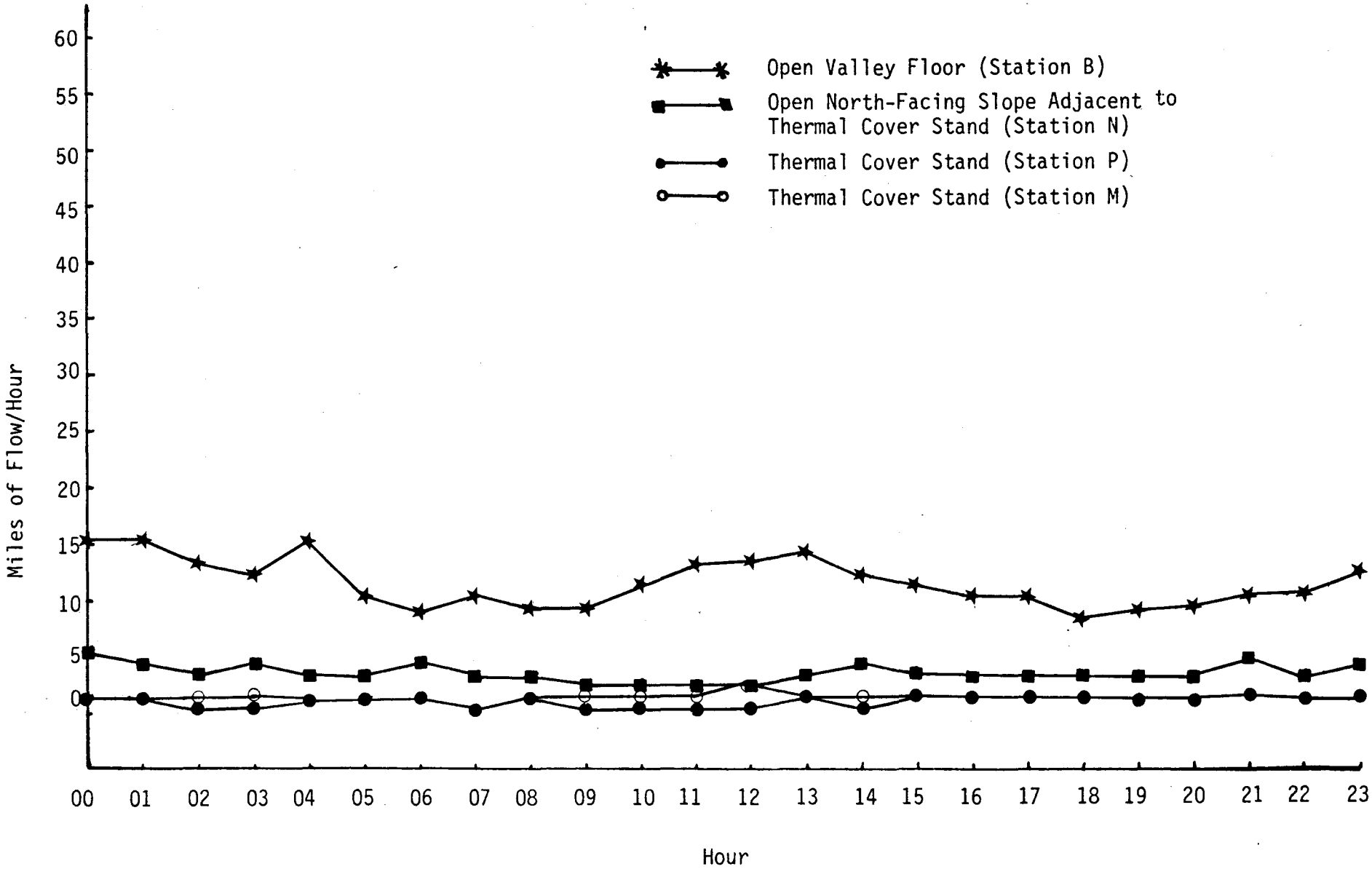


Figure 6. Average hourly ambient temperatures for February 15-19, 1980, at three sites on the Wall Creek elk winter range.

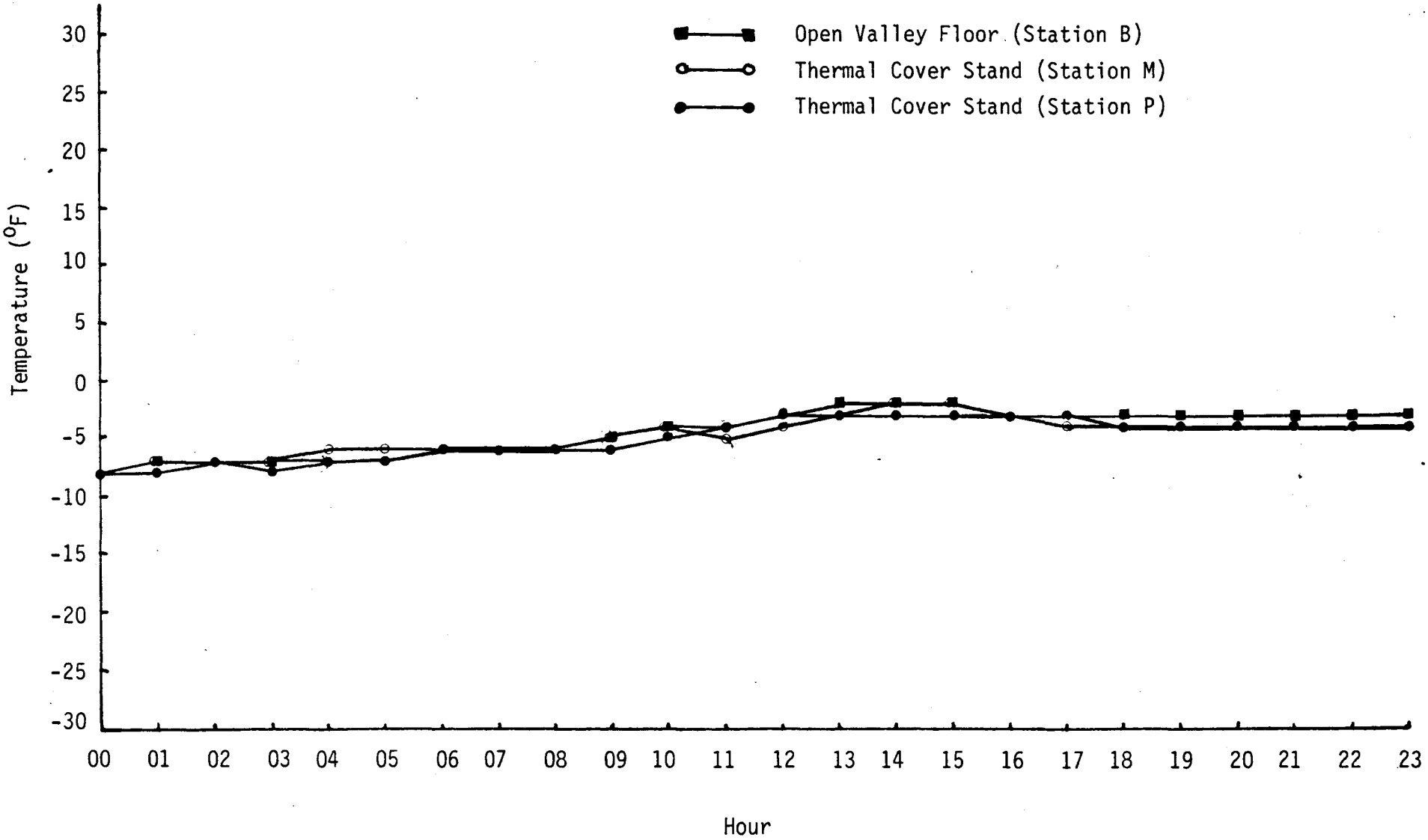


Figure 7. Average hourly wind flow/hour for February 15-19, 1980, at three sites on the Wall Creek elk winter range.

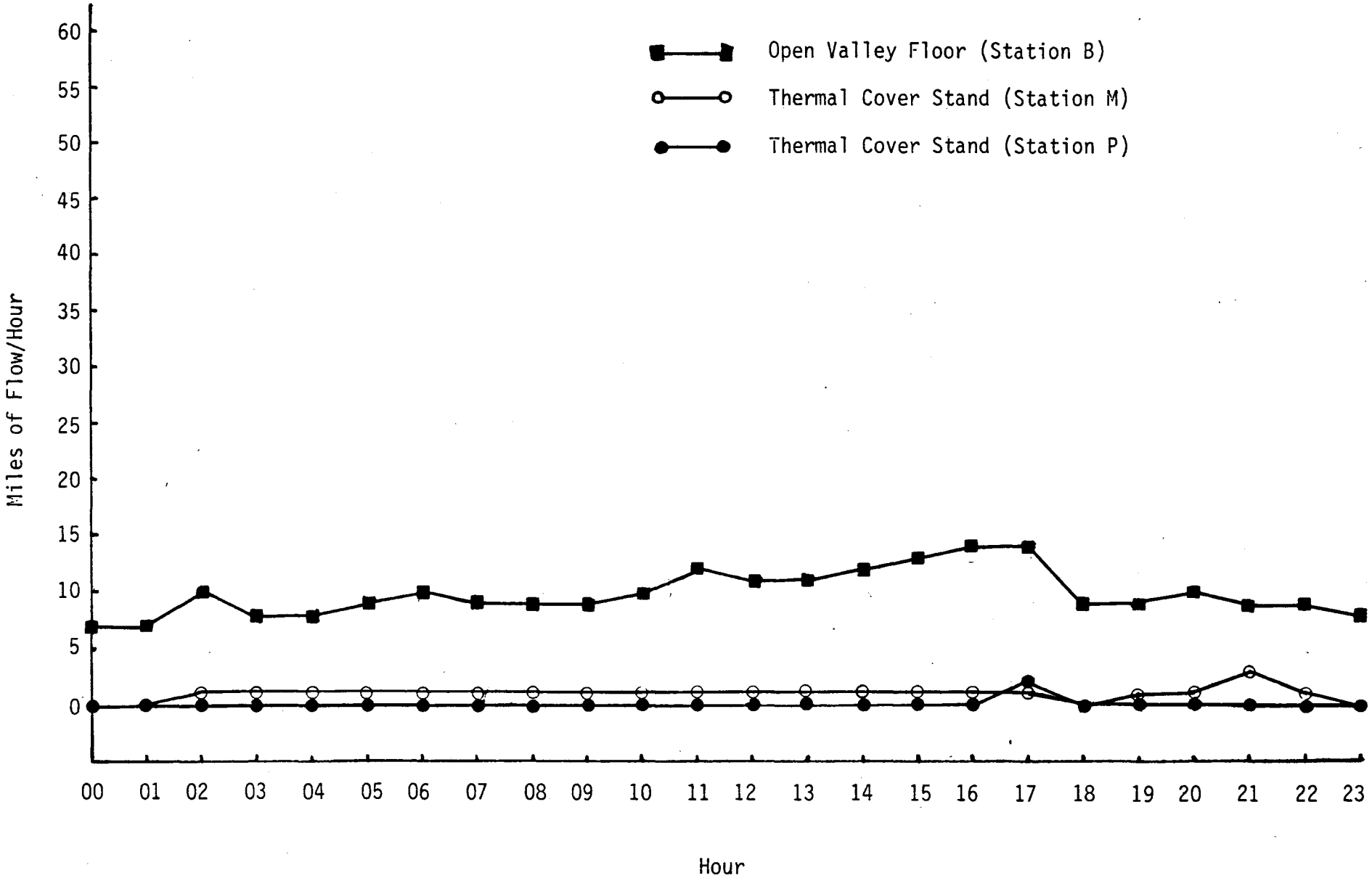


Figure 8. Average hourly ambient temperatures for March 14-18, 1980, at three sites on the Wall Creek elk winter range.

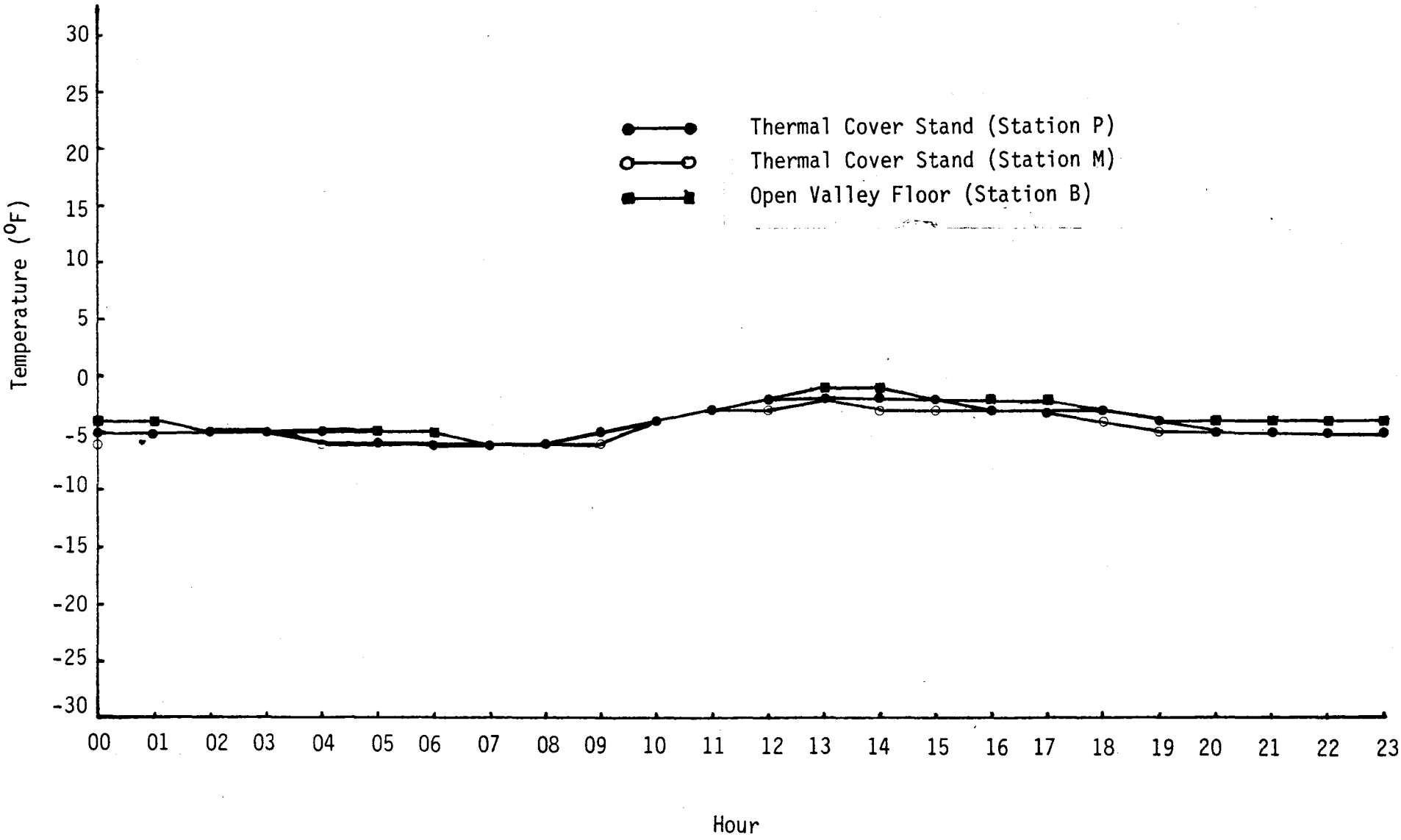


Figure 9. Average hourly wind flow/hour for March 14-18, 1980, at four sites on the Wall Creek elk winter range.

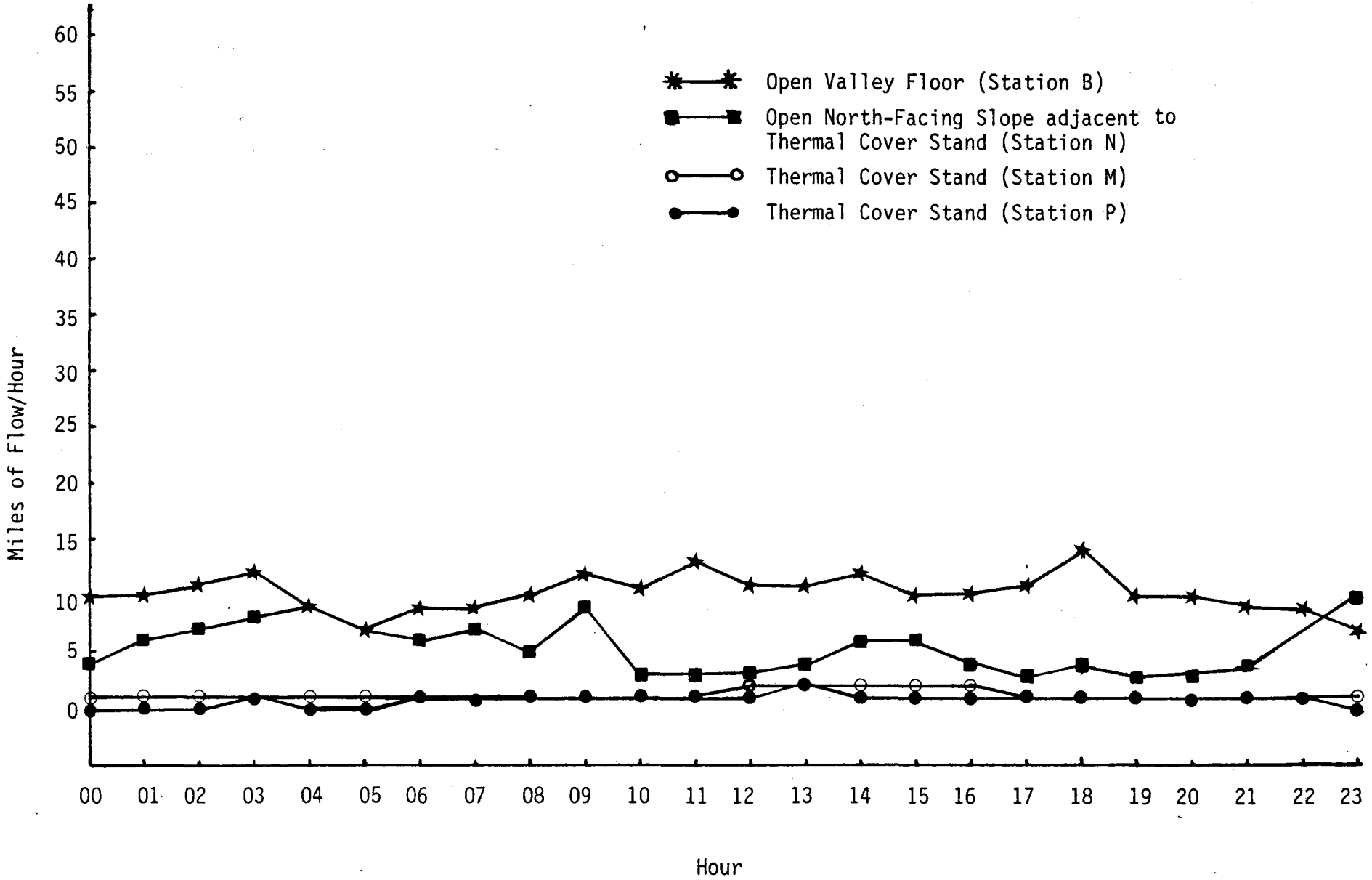


Fig.10. A comparison of protein (maintenance + gestation) requirements and dietary protein of a 236 Kg cow elk consuming 4.892 Kg/day.

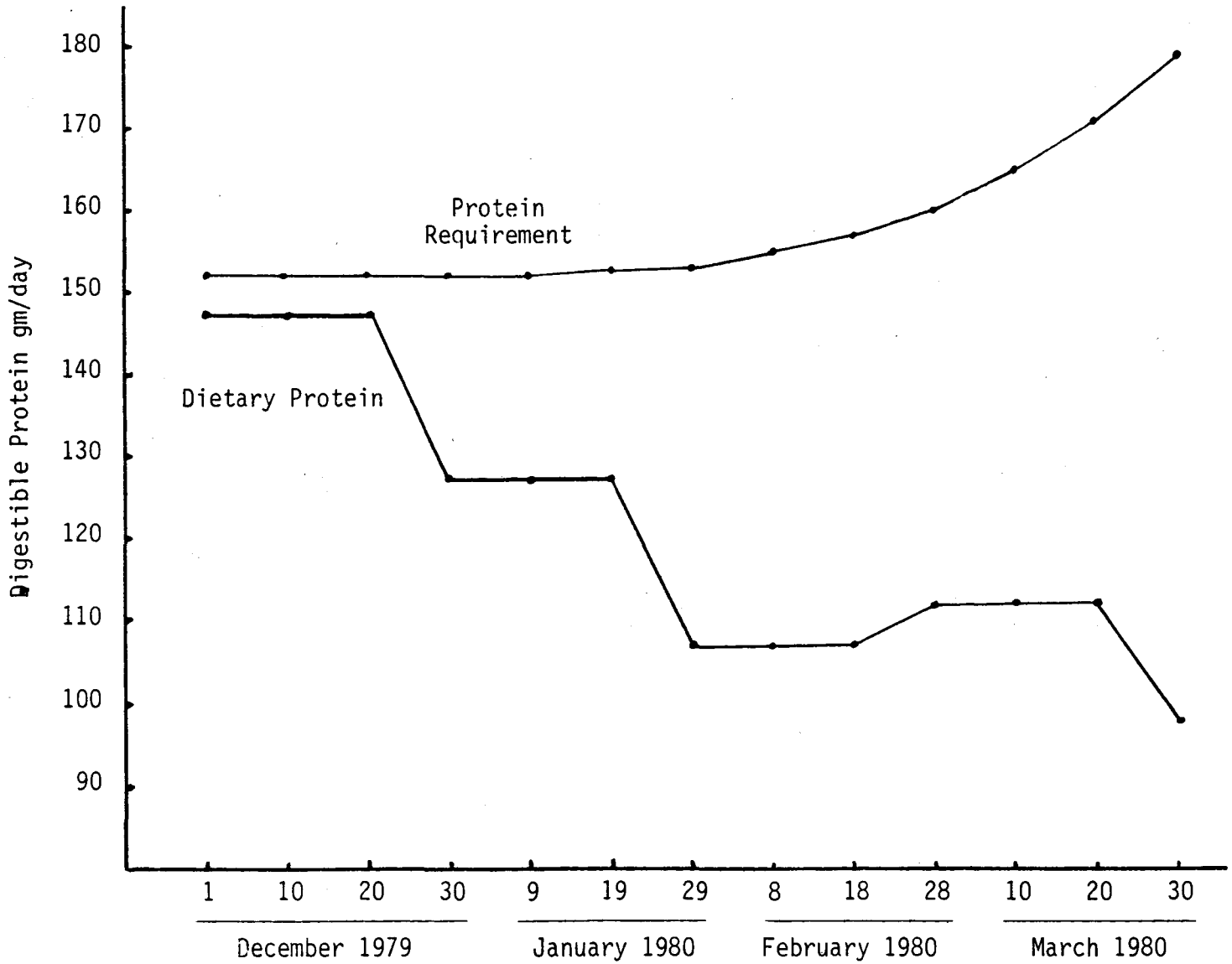
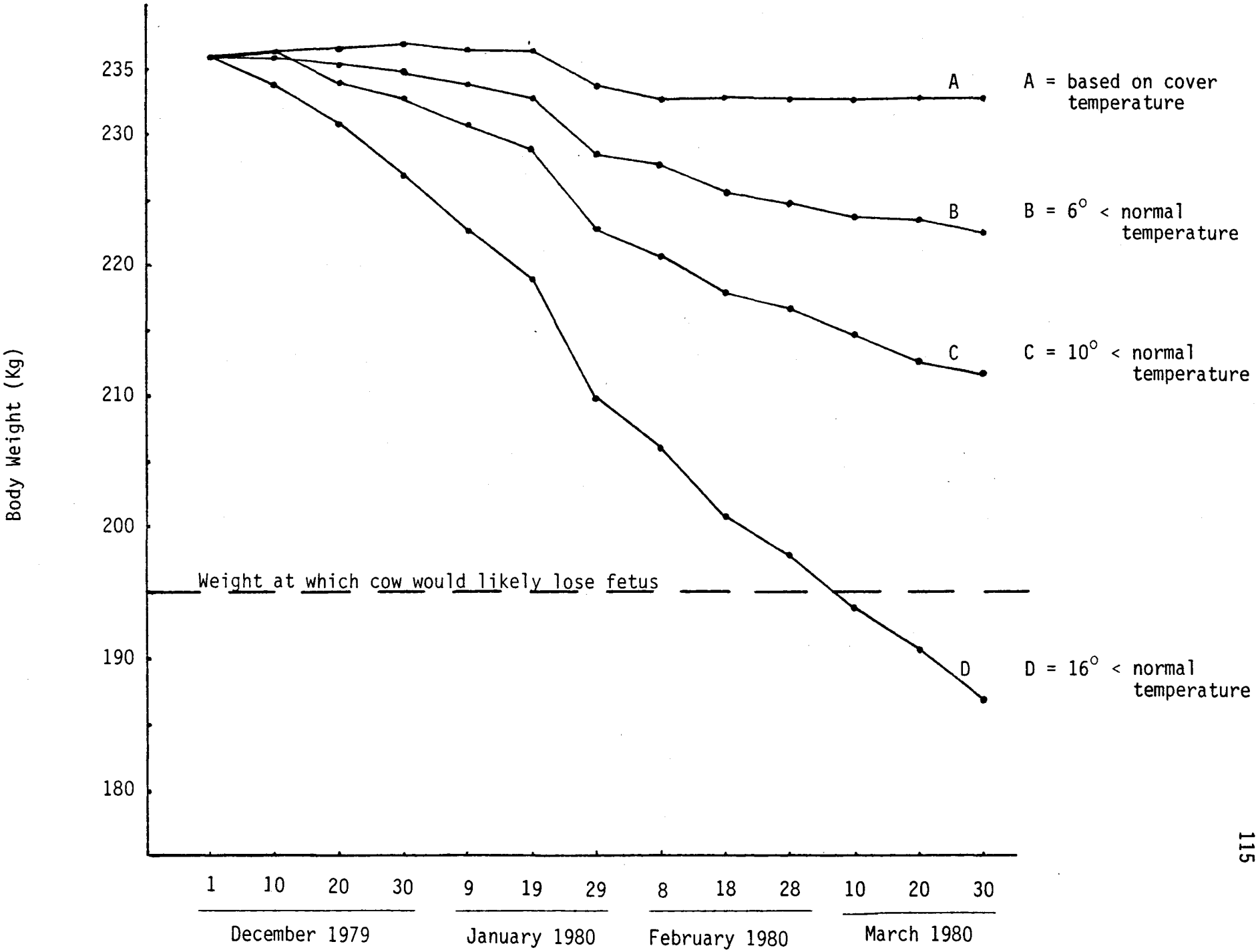


Fig.11. Trends in body weight of a 236 Kg cow elk based on energy expenditure (homeothermy + activity) and temperature regime.



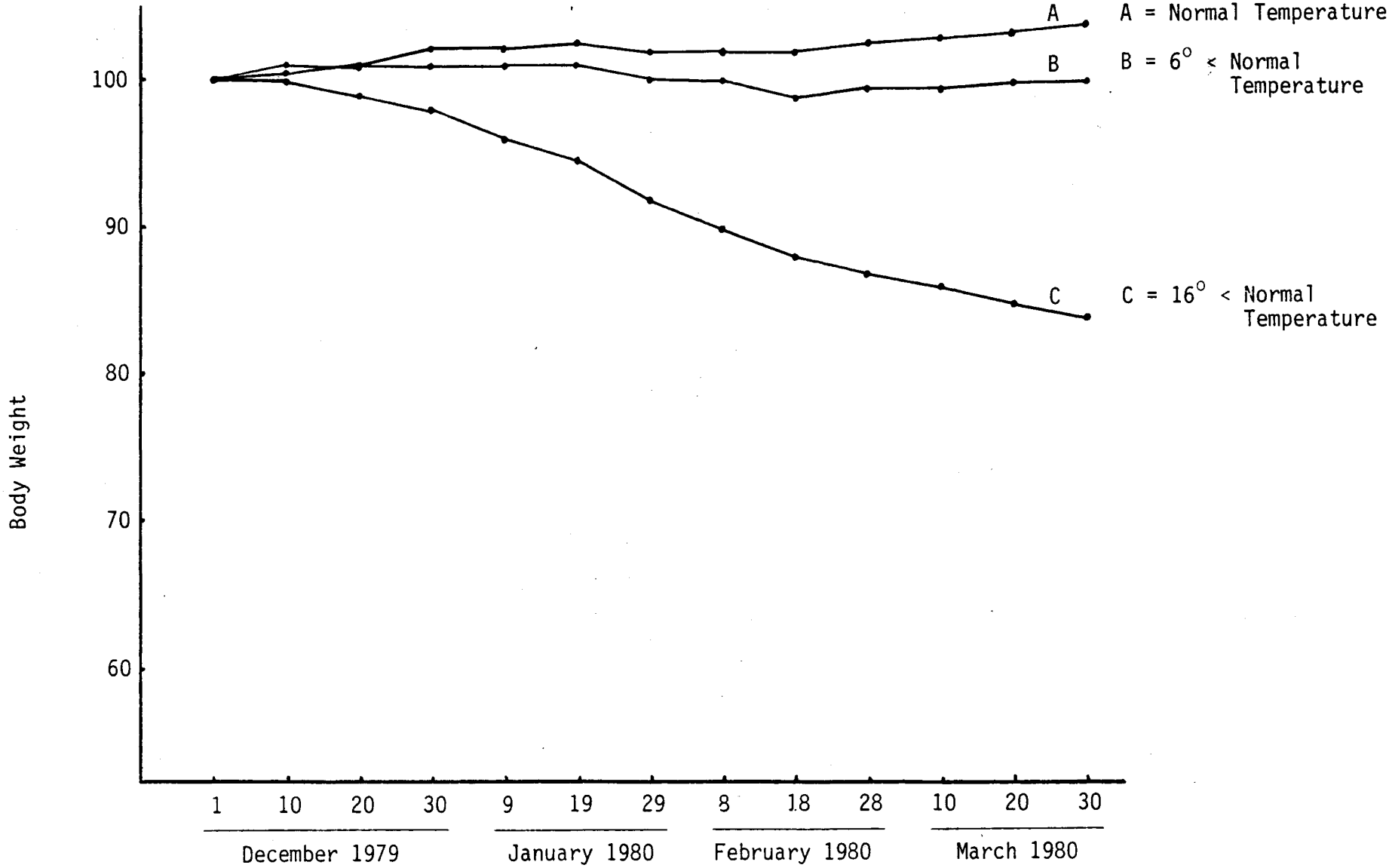


Fig. 12. Trends in body weight of a 100 Kg elk calf based on energy expenditure (homeothermy + activity) and temperature regime.

SUMMARY

Forest Service Management personnel in Region 1 have expressed concern about the potential detrimental impacts of spruce budworm damage to elk winter range. This study was established to assess the potential influence of defoliation of winter thermal cover on the winter nutritional stress of elk and to define distributional characteristics of defoliation throughout elk winter range. The targed study area was the Wall Creek elk winter range in the Madison River Valley, Montana. The host tree, Douglas-fir, occurred as small, isolated patches along the margins of the major winter foraging areas. These stands provide thermal cover for 800-1,000 elk each winter. Current defoliation levels in these stands are from moderately high to severe.

It was hypothesized that as winter thermal cover for elk was destroyed by defoliation, elk would be exposed to more severe weather conditions, greater nutritional intake by a cow elk to maintain homeothermy and adequate protein levels for proper fetal development.

Food habits of elk were determined by fecal analysis. Digestible energy and protein intakes were estimated through reconstruction of the diet, in vitro digestion of diet samples, and measurement for energy and protein content on a monthly basis for the winter period. The results were compared to estimates of energy and protein requirements of cow elk derived through modelling of the nutrition needs for the period in question.

Wind and temperature data from inside and outside of cover were used in the models to approximate the difference between adequate cover and cover loss through defoliation.

Reconnaissance studies were conducted to determine location, vegetation characteristics, and site properties of defoliated stands.

Elk diet on the study area were composed primarily of graminoids, which

are high in digestible energy.

Both dietary protein and energy declined throughout the winter.

Nutritional models comparing protein and energy intake of cow elk to that required for maintenance and gestation demonstrated a significant deficiency in protein and no deficiency in energy. Probable animal condition going into the winter period and larger available protein sources after the winter period when the fetus is growing at a much more rapid rate likely ameliorate the negative affects of this deficiency. Based on temperatures and wind flows measured inside and outside of cover, cow elk maintain adequate body condition to produce a viable calf in late spring or early summer. As long as animals are able to find some escape from winds, have early spring growth of vegetation available, and are not faced with long term continuous temperature regimes of -20^{o}F throughout the winter period, and are able to forage adequately throughout the winter, herd productivity as influenced by winter conditions is not likely to change from current levels.

Loss of thermal cover through defoliation would not influence winter nutritional stress experienced by elk in normal winter weather.

In general, spruce budworm defoliation tends to be comparatively high under the following conditions: Southward facing slopes, low elevations, ridges and upper slopes, steep slopes, more open tree canopies, dense trees, small diameter trees, short trees, short tree crowns, non-dominant status of individual trees. The relationships of defoliation with height to base of live crown and crown ratios are varied and appear dependent upon other variables. Relationship of defoliation to total basal area does not appear to be as important as is the size of the trees that are included in the basal area value.

Spruce budworm defoliation generally increases in response to conditions that are more unfavorable for development of Pseudotsuga menziesii usually drier and warmer environmental conditions. This is qualified to apply within certain environmental ranges that the spruce budworm appears restricted to because relatively dry, high elevation stands with apparently cooler environments are mostly uninfested by spruce budworms. Within the elevation range in question, plant communities are probably more sensitive to differences in moisture, whereas the spruce budworm population may be more sensitive to temperature.

Various site conditions are often indicated by understory composition. For example, stands with Festuca idahoensis are usually defoliated more than those with Calamagrostis rubescens. As a result, the community type classifications appear as useful indicators of variation in average defoliation potential. However, there is considerable variation in defoliation within each community type with differences in defoliation as related to site and other factors more evident within community types than between types. This would indicate that stand structure is more influential to the spruce budworm population than is the general environment across these communities. This may explain the difficulties involved in using community type classifications alone as indicators of spruce budworm defoliation potential.

In conclusion, community type classifications are valuable indicators of conditions that appear to influence spruce budworm populations, but variation within community types must be considered as well, with particular emphasis on variation in stand structure.

PROBLEMS ENCOUNTERED

No significant problems were encountered during the course of the study. Cooperation with State and Federal agencies was outstanding.

NEED FOR ADDITIONAL WORK

The study was conducted for a one year period only. The weather conditions experienced during the winter portion of the study were more moderate than normal. The weather conditions during the summer study were drier than normal. Additional studies would be useful to more fully document the variation in response to climate.

PLANS FOR PUBLICATION

Six publications are currently in preparation. Titles are as follows:

1. Forage production in relation to forest stand structure on there elk winter ranges in western Montana.
2. Nutritional quality trends in winter elk forage in the Madison River Valley, southwestern Montana.
3. Winter elk diet composition in the Madison River Valley, southwestern Montana.
4. Vegetation, site, and distributional characteristics of SBW infested forest communities in southwestern Montana.
5. Characteristics of elk winter thermal cover stands in southwestern Montana and northwestern Wyoming.
6. Environmental characteristics of elk winter thermal stands on the Wall Creek elk range in the Madison River Valley, southwestern Montana.

No journals have been chosen for submission of the manuscripts in progress.